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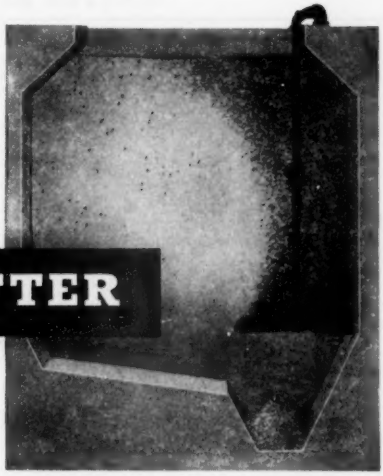

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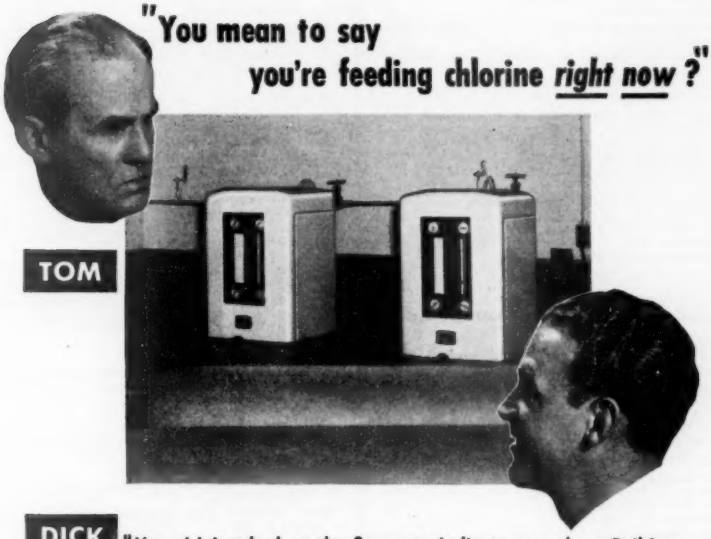

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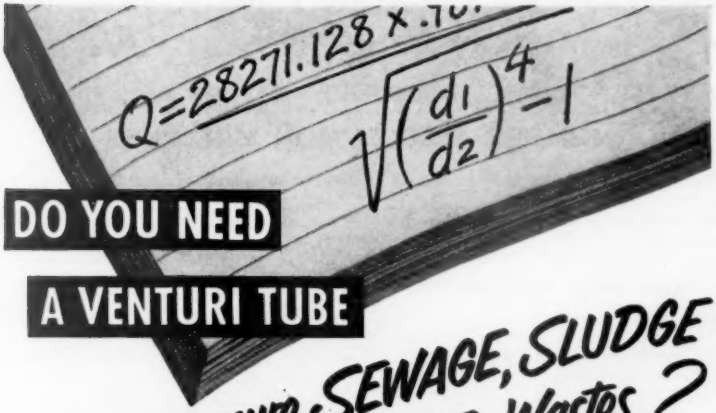

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New England Sewage Works Association	Sheraton-Biltmore Hotel, Providence, R. I.	Nov. 6–7, 1951
North Carolina Sewage and Industrial Wastes Association	Robert E. Lee Hotel, Winston-Salem, N. C.	Nov. 12–14, 1951
Oklahoma Water, Sewage and Industrial Waste Conference	Oklahoma A. & M., Stillwater, Okla.	Dec. 3–7, 1951
New York Sewage and Industrial Wastes Association	Hotel Statler, New York, N. Y.	Jan. 17–18, 1952

Federation of Sewage and Industrial Wastes Associations in conjunction with New York Sewage and Industrial Wastes Assn.
Hotel Statler, New York, N. Y.
October 6–9, 1952

Texas Water and Sewage Works Association	Texas A. & M., College Station, Texas	March 9–13, 1952
Arizona Sewage and Water Works Association	Maricopa Inn, Mesa, Ariz.	April 3–5, 1952
Arkansas Water and Sewage Conference	Engineering Building, University of Arkansas, Fayetteville, Ark.	April 7–9, 1952
Montana Sewage and Industrial Wastes Association	Northern Hotel, Billings, Mont.	April 10, 1952
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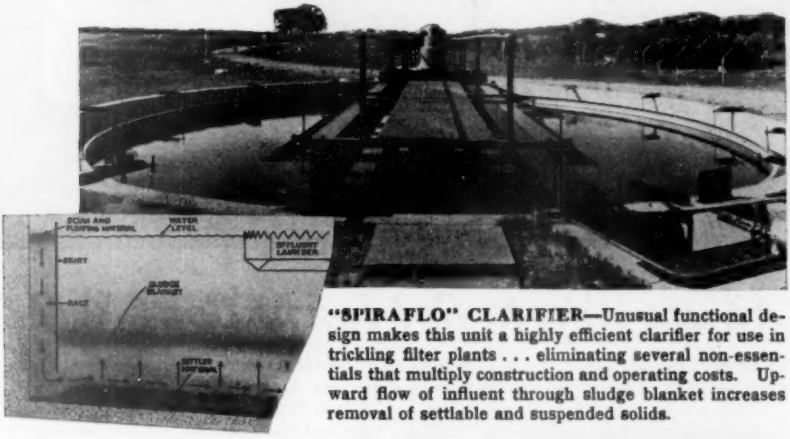

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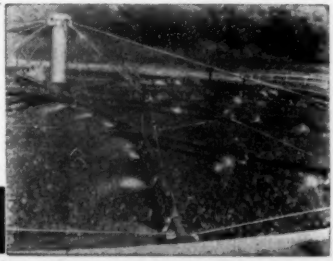

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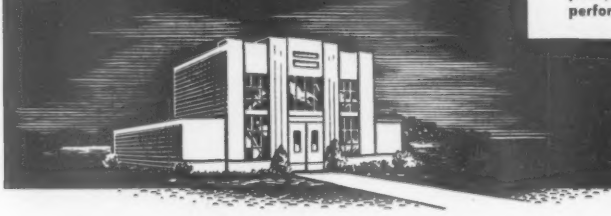

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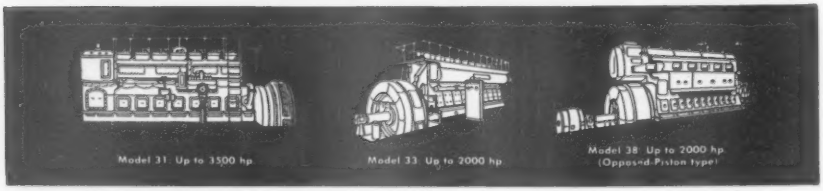

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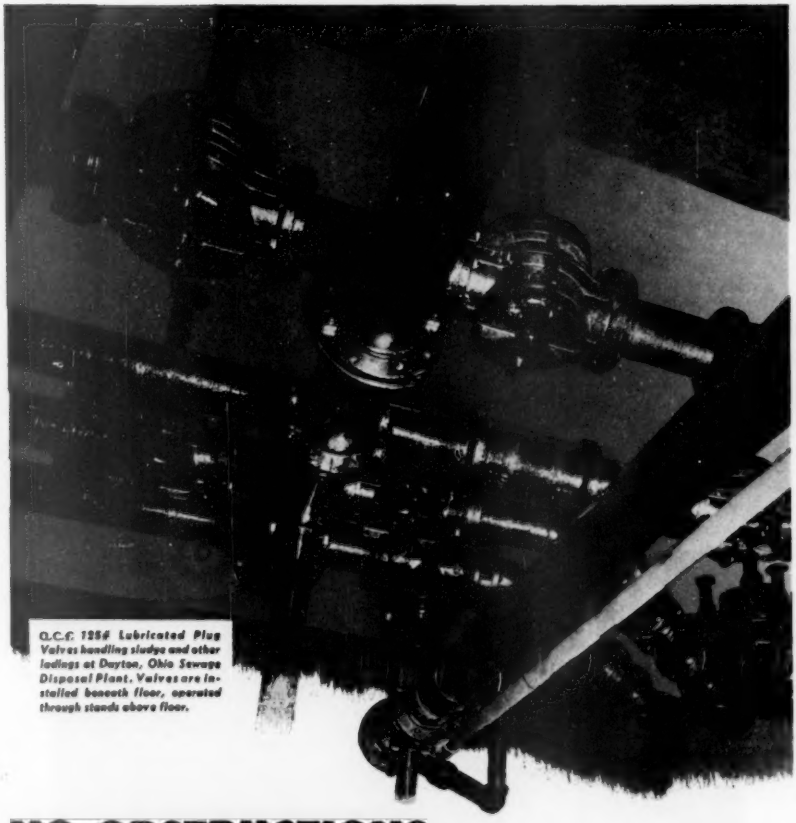

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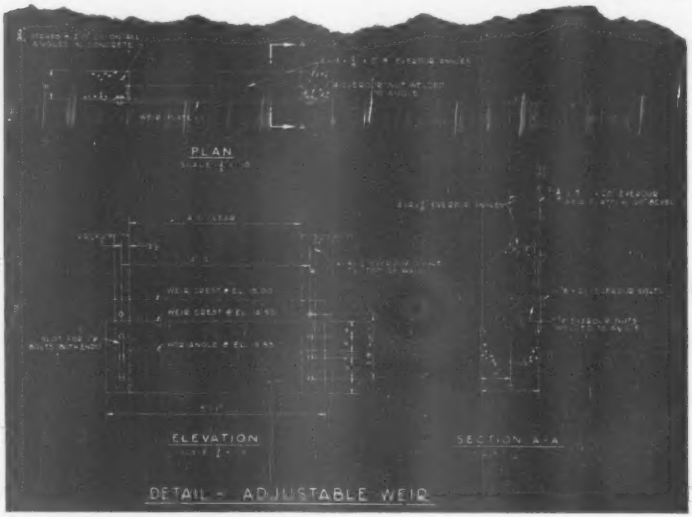

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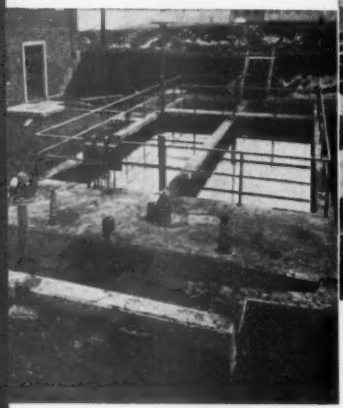
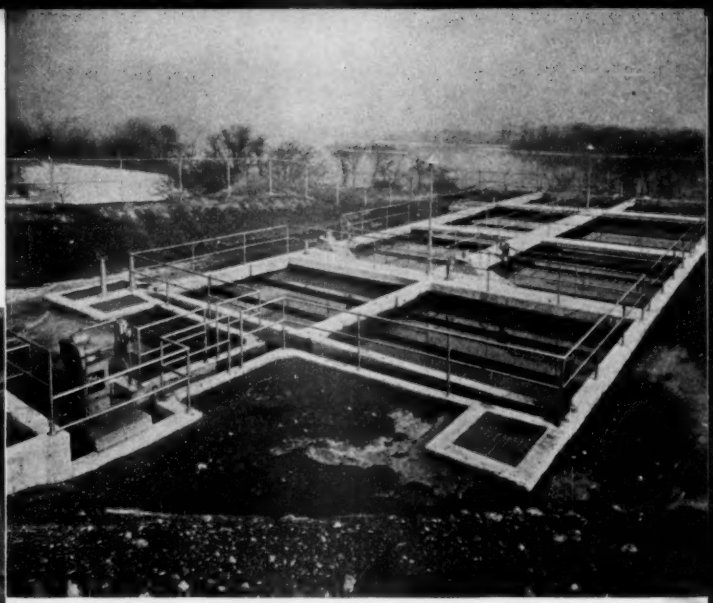
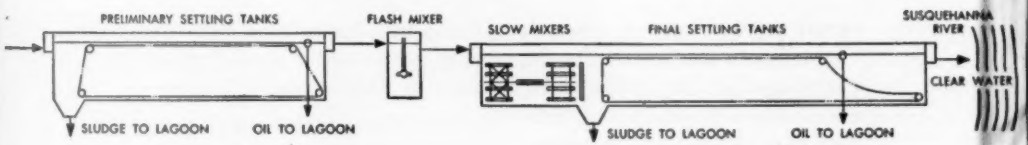
Settleable solids and floating oils are separated in the two 9 x 52 x 6 ft. preliminary settling tanks by L-B Straightline Collectors and Rotoline Skimmers.





Link-Belt flash mixer intimately mixes alum and lime for flocculation. Slow mixing is performed by two L-B mixers, parallel to the flow, whose speed is varied by P.I.V. Variable Speed Drives. Two final settling tanks, 18 x 90 x 8 ft., also have L-B Straightline Sludge Collectors and Rotoline Skimmers.

How to halt stream pollution



Completely LINK-BELT-equipped waste treatment plant removes oil and suspended solids at world's largest freight classification yard

COOPERATING with Pennsylvania's Clear Streams Program, the Pennsylvania Railroad recently completed an efficient waste treatment plant at their Enola (Pa.) yards. Designed by Gannett, Fleming, Corddry & Carpenter, Inc., consulting engineers, the plant is laid out for an average flow of 2.0 mgd, with a 4.0 mgd maximum storm flow.

To separate efficiently the solids and oils resulting from locomotive washing, ash quenching, sanitary sewage and storm water, surface loading is carefully controlled. At design flow, the preliminary tanks are limited to 2140 gal. per sq. ft. per day . . . the final tanks to 260. Sludge and oil removed are lagooned.

Whether it's for a compact industrial waste plant or a large metropolitan water or sewage treatment works, you'll find it pays to rely on Link-Belt equipment. Our sanitary engineers will work with your consultants and chemists — help you get the best in modern water, sewage or industrial liquids treatment.

LINK-BELT COMPANY: Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Houston 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8, Springs (South Africa). Offices in principal cities. 12,500-A

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

Difficult suburban sewer problem solved with

CONCRETE PIPE

THE Alewife Brook Conduit project in Medford, Arlington, Cambridge and Somerville, northern suburbs of Boston, posed an unusual construction problem that was solved with concrete pipe.

The installation of this difficult, trunk-line sewer required that pipe be placed in open cuts, in tunnels under streets, playgrounds and a railroad, along a brook generally well below the existing water table and finally under the Mystic River.

The project required 8310 ft. of 60-in. and 66-in. (ASTM Specification C76, Table I and Table II) reinforced concrete pipe using two rows of circular reinforcing steel.

This is but another example of the adaptability of concrete pipe. Its structural strength and rugged durability have been proved by many decades of heavy-duty service.

Concrete pipe provides maximum hydraulic capacity. Its tight joints and uniformly dense structure insure minimum infiltration and leakage. It is moderate in first cost, requires little upkeep, lasts longer. Result: ***low-annual-cost*** service.

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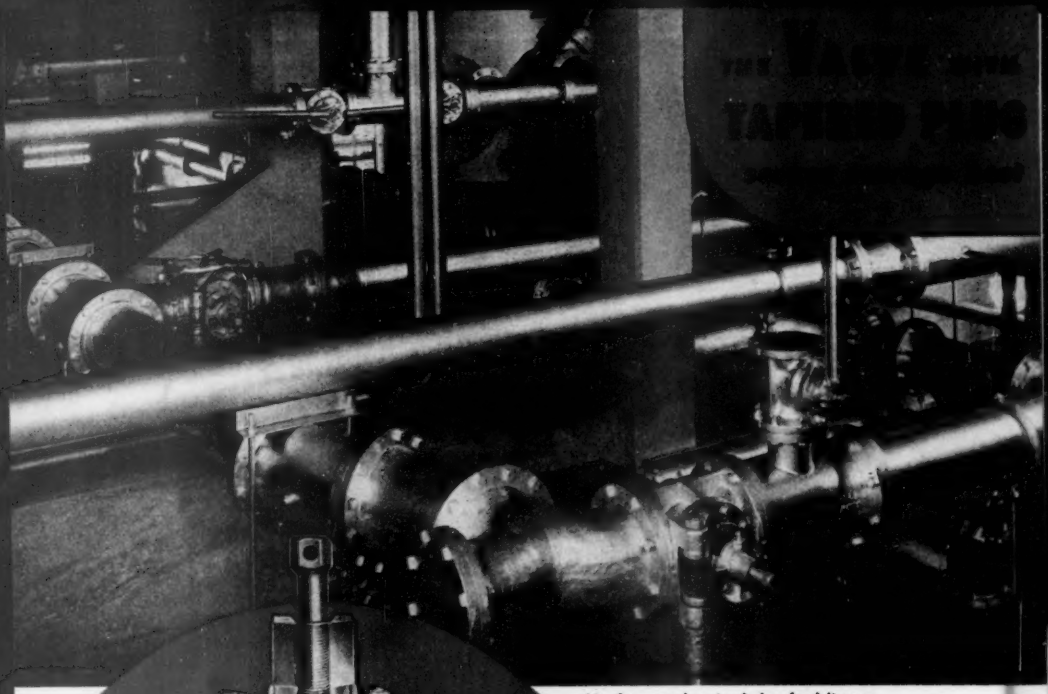
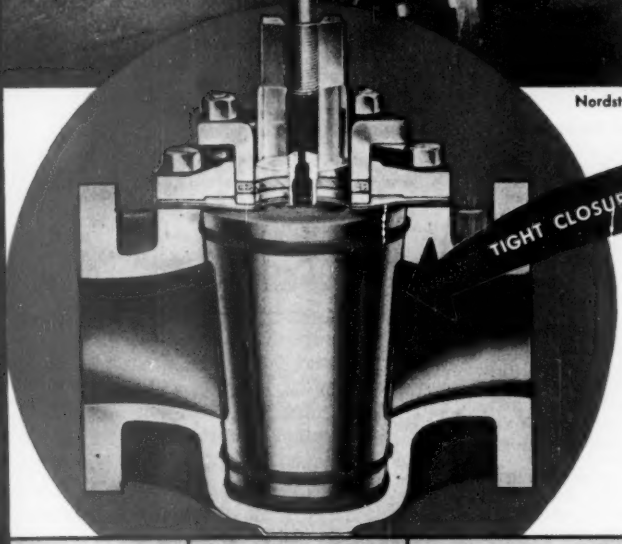


Nordstrom valves in sludge feed lines



TIGHT CLOSURE WITHOUT STICKING

Nordstrom lubricated valves present four unexcelled features essential for sewage disposal service. (1) *Tapered plug* which permits jacking by hydraulic means in event plug becomes too tight; (2) *"Sealdport" lubrication* which applies a pressurized seal of lubricant around each port and prevents line fluid from contacting the valve seat; (3) *flexible diaphragm shoulder seal*, an anti-friction means of preventing gland leakage, but permitting jacking of plug; (4) *automatic lubrication* with Hypermatic, the miracle lubricant. Specify these vital features when specifying for your sewage plant valves.

"SEALDPORT" SURROUNDS PORTS
Seals each port against leakage

RESILIENT SHOULDER STEM SEAL
Allows jacking of plug

CORROSION AND EROSION EFFECTIVELY RESISTED
Lubricant pressure protects parts

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REPAIR PARTS AVERAGE ½ OF 1%
As compared with valve sales

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...Equally Efficient for Coagulation of WATER and SEWAGE!

FOR WATER WORKS

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3. Promotes better settling and longer filter runs.
4. Aids in reduction of tastes and odors.
5. Has no chlorine demand.
6. Is a *low cost* coagulant.
7. Superior in tests against other coagulants.
8. High in quality. Its constant uniformity can be depended upon.

Aluminum Sulfate is almost universally accepted by water experts as the best coagulant for removal of turbidity, color and bacteria from water . . . and General Chemical Aluminum Sulfate is the outstanding choice the nation over. That's because its high quality and constant uniformity have given it a time-tested reputation for reliability among operating men in towns and cities all over America.

Municipal officials in charge of sewage treatment also find that clarity of sewage effluent is easily obtainable with General Chemical Aluminum Sulfate for the many reasons outlined above. For your water and sewage disposal systems, specify General Chemical "Alum"—*preferred by most American cities.*

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1. Clean, easy to handle.
2. Dry feeds well or dissolves readily for solution feeding.
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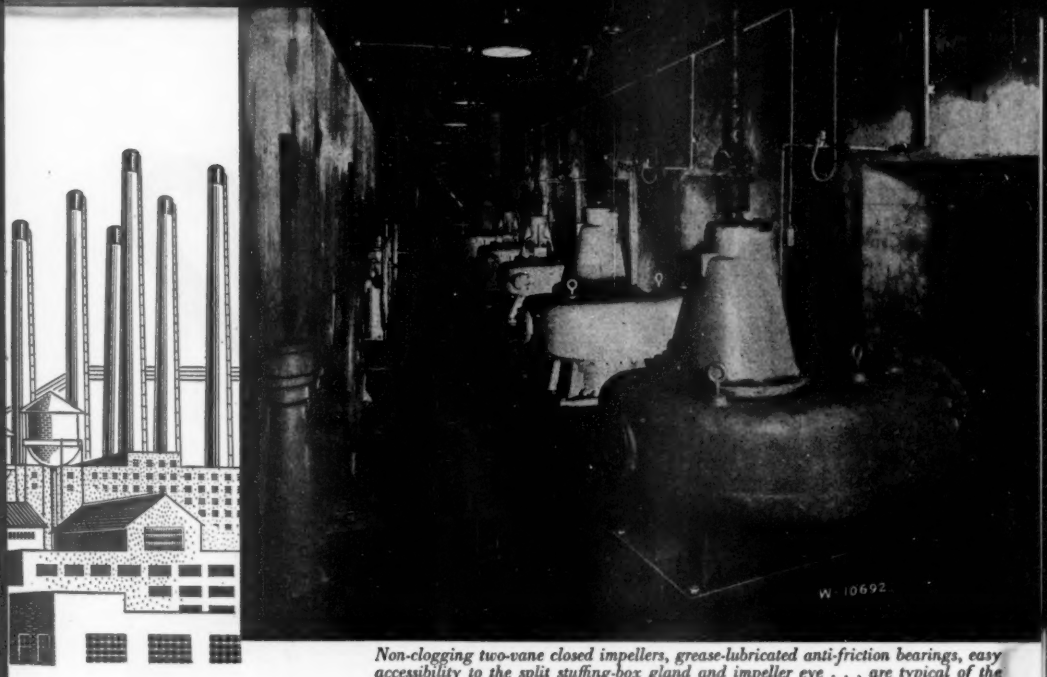


Non-clogging two-vane closed impellers, grease-lubricated anti-friction bearings, easy accessibility to the split stuffing-box gland and impeller eye . . . are typical of the many Worthington MIXFLO *features assuring low-cost, trouble-free sewage pumping.*

How is Bridgeport's Sewage Pumped?

It's full of industrial waste . . . a problem built for Worthington Pumps

Here's another municipality which has turned its sewage pumping over to Worthington—100%.

These five Worthington Vertical MIXFLO sewage pumps are located in Bridgeport's Westside sewage plant—installed in 1946. Three are 20-inch, two are 16-inch MIXFLOS.

Bridgeport's Eastside plant duplicates these five pumps, and in addition uses two Worthington dry vacuum pumps and a Worthington air compressor.

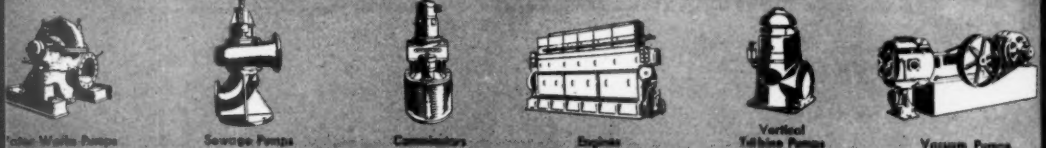
In many other places, too, Worthington—world's largest manufacturer of pumps—is keeping pace with developments in sewage treatment and disposal by furnishing pumps of utmost dependability.

The Worthington MIXFLO line offers the industry's widest choice of sizes and types. So take a tip from New York, Chicago, Philadelphia, Bridgeport—find out why *there's more worth in Worthington.* Write Worthington Pump and Machinery Corporation, Public Works Division, Harrison, New Jersey.

WORTHINGTON

SEWAGE PUMPS

W.1.



155 MGD

are "treated" right ...at Portland!

View of the Rex equipped primary tanks in the new Portland, Oregon, Sewage Treatment Plant

Consulting Engineers:

Stevens & Koon

John W. Cunningham & Associates

The engineers who designed the new Portland, Oregon, Sewage Treatment Plant—the largest in the Northwest (designed to handle 155 million gallons daily)—knew they must specify the finest equipment available—equipment that would assure low-cost, efficient operation for a project of this size. Naturally, they chose Rex®.

Rex Sewage Treatment Equipment has, over the years, built a reputation of which engineers and municipal officials are becoming increasingly aware. This reputation—for quality equipment which gives years of service at the lowest possible operating and maintenance cost—is perhaps our greatest asset. We mean to live up to it in the years ahead.

Rex equipment installed at the Portland plant includes:

- **2 type MAX Mechanically Cleaned Bar Screens**
- **2 No. 8F Triturators**
- **12 Longitudinal Conveyor Sludge Collectors**
- **4 Cross Conveyor Sludge Collectors**
- **12 Worm Gear-operated Roto-Skim Collecting Pipes**

For more information on this installation and any Rex equipment, call your nearest Rex Field Sales Engineer or write to Chain Belt Company, 1606 W. Bruce Street, Milwaukee 4, Wis.

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Consulting Engineer Steeg *specifies*

INERTOL PAINTS

throughout Noblesville, Indiana, Sewage Plant

Glamortex, an alkyd resin enamel, provides a durable, mar-resistant finish to piping and machinery.

Ramuc Utility, a glossy, chlorinated rubber-based enamel, protects and beautifies walls, ceilings, concrete and masonry.

● To meet the rigid requirements of durability and attractiveness for this modern sewage plant, Mr. Henry Steeg, Indianapolis consulting engineer, specified the use of Inertol Paints. He knew from experience that these paints would far exceed the demands of hardness, elasticity, chemical inertness and beauty. The superiority of these quality paints, developed specifically for sewage plant usage, has been proved in hundreds of installations throughout the country.

Here is *another* "case history" from our growing file, where expert consulting engineers *specify* Inertol Paints because of the guarantees of long-lasting performance.

If you are not familiar with the merits of this quality line, our Field Technicians will be pleased to discuss it fully with you at your office. Or if you prefer, write us today for the "Painting Guide," an invaluable aid for Design Engineers, Specification Writers, Contractors and Plant Superintendents. Address office nearest you.

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how Worcester, Mass., modernized 1925 Sewage Plant with an

Accelo® Filter *system*

To give Worcester a modern 20,000,000 g.p.d. treatment plant, consulting engineers replaced 1925 equipment with the Infilco Accelo Filter system with *direct recirculation* and *positive aeration.* The system has 8 rotary distributors 176 ft. in diameter with aero-spray nozzles. Excellent distribution is obtained over filter surfaces with vigorous growth of bacterial gel. Three Infilco PD Clarifiers (foreground) provide effective final sludge removal.

Specify Infilco for:

Increased Filter Efficiency
No Increase In Clarifier Size
Increased Capacity
No Clogging, Sloughing Or Ponding
No Odors
Reduced Psychoda Fly Nuisance

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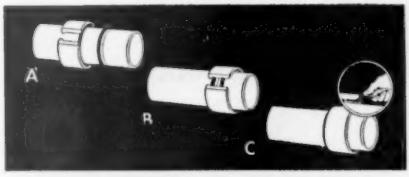
HERE'S HOW THE RING-TITE JOINT WORKS:



(a) Start of assembly. Two rubber rings and a Transite sleeve (cut away to show position of rings) are placed on one of the two pipe ends to be joined; (b) Final position. Sleeve centered over both pipe ends, with the rubber rings tightly compressed between sleeve and pipe; (c) Checking joint for proper assembly. This is done with a simple gauge immediately after joint is made . . . *before backfilling.*

Transite is a registered Johns-Manville trade mark

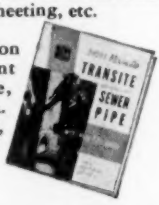
Specify TRANSITE SEWER PIPE with new RING-TITE JOINTS

Whether you plan to extend existing sewer lines, or build a complete new system, you'll want to check into the money-saving possibilities offered by Transite Sewer Pipe with its new Ring-Tite Couplings.

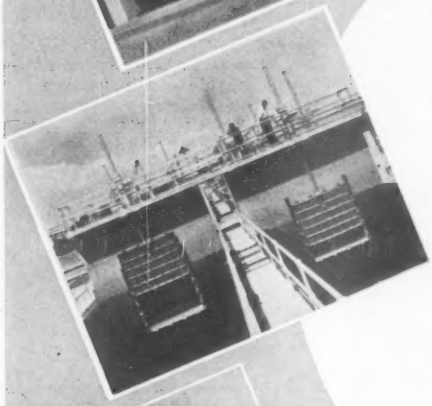
Without the need for hot jointing compounds, this factory-made coupling is quickly assembled to make a tight joint that *stays* tight in service. This, plus the fact that Transite's long 13-foot lengths mean *fewer* joints in the line, cuts infiltration to a minimum. Thus, the load on the disposal plant is cut down, treatment costs reduced, plant capacity conserved for future needs. And, in planning new systems, smaller treatment plants and smaller diameter sewers may be considered . . . with savings in money, time and labor.

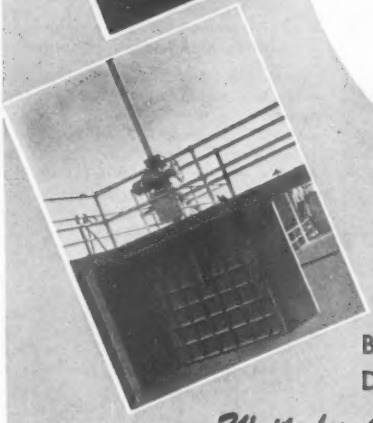
Important installation savings are possible, too, with Transite Sewer Pipe. Its relatively light-weight, long 13-foot lengths, and easy-to-assemble Ring-Tite Couplings speed completion of the line. It can be readily cut on the job for closures and branch connections. And its high flow capacity (Manning's n-.010) often permits flatter grades and shallower trenches with savings in excavation, sheeting, etc.

For further information about asbestos-cement Transite Sewer Pipe, write for folder TR-103A. Address Johns-Manville, Box 290, N. Y. 16, N. Y.



JM PRODUCTS **Johns-Manville TRANSITE SEWER PIPE**





Pekrul Gates

PEKRUL MODEL 56 GATES with Philadelphia Limitorque Model M30 Motorized Lifts in operation at Denver Sewage Disposal Plant.

PEKRUL GATES are engineered to meet the most rigid requirements for:

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Irrigation
Water Works
Dams
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CREATIVE FILTER ENGINEERING

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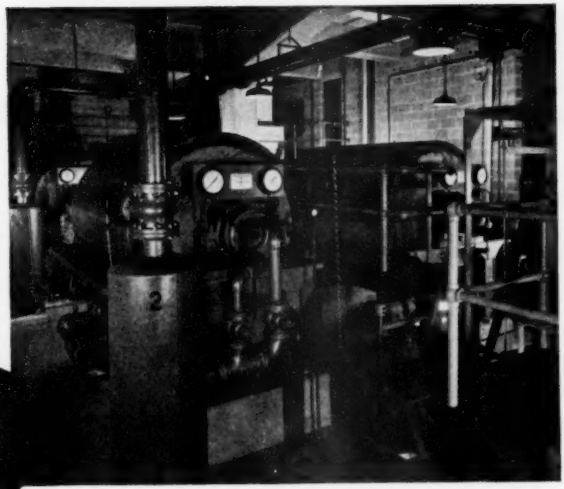

Section of the filter room showing Conkey Sludge Filters in recently opened Bridgeport primary treatment plant.

Newly completed Bridgeport, Conn., Sewage Treatment Plant uses Conkey Sludge Filters

Bridgeport's new East Side primary treatment plant handles a high percentage of diversified industrial wastes. Careful planning plus several unique innovations were required to successfully dewater and incinerate this sludge. It was essential that the sludge filters . . . *heart of any sewage treatment plant* . . . would dewater rapidly, continuously and automatically at the lowest possible cost. Conkey Sludge Filters were selected and have provided *better filtration* . . . fulfilling each necessary requirement perfectly.

Typical Conkey Sludge Filter features are the effective plastic backing plates for filter cloth support, the Uscolite pipe lines and drainage bells, the efficient double scraper arrangement, specially formulated protective coatings and many newly developed components made of special plastics.

Bridgeport, Chicago, many other cities . . . private industry in many places . . . all have found that creatively engineered Conkey Sludge Filters "do a better job" and do it at minimum cost. Bulletin No. 100 on Conkey Filters belongs to every progressive sewage engineer. Write for your copy today.

Other General American Equipment:

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to aid peak
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Collect and Sell your Iron and Steel Scrap

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The average pipe yard has some or all of the following sources of scrap metal, according to whether pipe is used for water, gas, sewerage or industrial service:

Obsolete fittings; cut pipe (short pieces of distribution or service pipe); damaged hydrants, valve boxes, manhole covers, etc. It all adds up to a vital contribution to defense production.

Collect your scrap now. Phone your nearest scrap dealer. He wants what you have *but quick*, and pays good cash prices.

CAST IRON PIPE RESEARCH ASSOCIATION . . . CHICAGO

SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 23 **OCTOBER, 1951** **Number 10**

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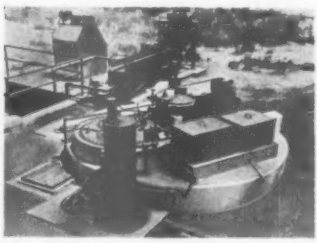
VERSATILE...

is the word for the Dorrco Vacuator*

Here are Three Ways it can be utilized to solve your problems . . .

AS A PRE-TREATMENT UNIT

1 At overflow rates of 5000 to 7500 gal./sq. ft./24 hrs., the Vacuator can serve as a complete pre-treatment unit, removing scum, grit and a substantial percentage of suspended solids—also thickening excess secondary sludges.



EXAMPLE:

At McAlester, Oklahoma's new West Sewage Treatment Plant a 12' dia. Vacuator removes scum, grease and grit from incoming screened sewage, prior to two-stage trickling filter treatment. Operating results show removals of 46.6% of suspended solids and a 28.4% reduction in B.O.D.

AS A SCUM-REMOVAL UNIT

2 At overflow rates of 5000 gal./sq. ft./24 hrs., the Vacuator can be used for the treatment of oil, cannery, packing house, laundry and similar tough-to-handle wastes.

EXAMPLE:

Scum-forming cannery wastes virtually put the Palo Alto, California Sewage Treatment Plant out of commission five months of the year. A 35' dia. Vacuator, followed by secondary treatment, completely solved the problem by removing an average of 43.6% of suspended solids, 58% of settleable solids and 8.4% of B.O.D. during the canning season.

AS A GREASE-REMOVAL UNIT

3 Overflow rates as high as 10,000 gal./sq. ft./24 hrs. can be used when the primary function of the Vacuator is grease removal from domestic or industrial wastes.

EXAMPLE:

At Patuxent River, Maryland, a 14' dia. Vacuator removes heavy "slug loads" of grease ahead of primary treatment. Removals average 50% of suspended solids and a 51% reduction in B.O.D., enabling the standard Dorr Clarifier which follows to function smoothly without auxiliary equipment.

These examples illustrate but three of the many ways in which the compact, three-product Vacuator is successfully solving difficult problems. If you think vacuum-flotation could help you, write for Bulletin #6301.

*Reg. U.S. Pat. Off.

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Sewage Works

CONCENTRATION OF ACTIVATED SLUDGE *

By John J. Wirts and Frank J. Ausflug

Superintendent and Operator, respectively, Easterly Sewage Treatment Plant, Cleveland, Ohio

In 1946 Bloodgood (1) concluded that "It is difficult to operate concentration tanks without odor nuisance. Consequently, they should be located so that there will be no objectionable conditions." His conclusions are still valid today, but a satisfactory alternate process for the "Concentration of Activated Sludge" has been found and put into practice. The alternate process is the "Concentration of Mixed Liquor," which might be a more appropriate title for this paper.

In an unpublished preliminary report on "Concentration of Activated Sludge," dated February 29, 1944, submitted to the Department of Public Utilities, a description of the process was as follows:

1. The adaptation of a final clarifier for the purpose of concentrating activated sludge.
2. The control of the clarifier in such a manner as to produce a concentrated sludge containing 30,000 p.p.m. of suspended solids.
3. Regulation of the activated sludge process in order to produce automatic removal of excess sludge, which predetermines a relatively constant composition of the aeration mixture.

This description adequately covers the process as used at the Cleveland Easterly plant today, with the exception that two of the 16 final clarifiers are used for this separate operation. It should be mentioned that the process has been in continuous operation for the past seven years, without odors or nuisance of any kind. The location of the Easterly plant is such that any odor would not be tolerated by the residents of the surrounding Class A area (Figure 1).

Advantages of Concentration

Before discussing the details of operation control of the concentration process, it may be well to point out several quite obvious advantages in removing water from activated sludge. Where digestion is used both the tank capacity and the heating facilities are more effectively used when the sludge is concentrated. Similarly, the capacity of vessels used to barge the sludge to sea is an important consideration. When activated sludge is filtered mechanically the filter capacities and dryer capacities are greatly benefited by concentration of the sludge. In those few cases where the sludges are transported a considerable distance by pumping, removal of the bulk of the water results in a saving in power and pumping time.

Effect on Operation Control

The rate of mixed liquor feed to the concentration units is controlled by raising or lowering the influent gates to the clarifiers. This adjustment is infrequent and is only necessary to

* Presented at 25th Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Columbus, Ohio; June 20–22, 1951.

FIGURE 1.—Final settling tanks at Cleveland Easterly sewage treatment plant. The two tanks at left are used exclusively as low-rate clarifiers for the concentration of activated sludge mixed liquor.

compensate for the addition or removal of aeration capacity during aeration tank maintenance. Best results have been obtained when the rate of feed averages 400 g.p.d. per square foot of surface area. A single setting of the influent gates causes the system—that is, the aeration tanks, final tanks, and concentrators—to reach a state of balance for that particular gate setting. In this case, for want of a better term the word "balance" is used to indicate a condition of relatively constant composition of the aeration mixture. This, of course, is observed by the daily composite analyses of the mixed liquor suspended solids. In effect, the concentrators "float" on the connected aeration tank system and automatically hold the suspended solids in the mixed liquor between a narrow band of minimum and maximum. The variation between the minimum and the maximum is approximately 260 p.p.m., which is ideal for control of the activated sludge process.

An explanation of this governing action of the concentration units is simplified by the consideration of the dry solids content of the feed. Whenever the mixed liquor dry solids in the aeration system tend to increase, due to an increase in plant loading, the constant volume of feed to the concentrators transports an increased amount of dry solids. This condition obtains during storms and during week days (usually Mondays and Tuesdays). Conversely, during times of reduced plant loadings (usually Saturdays, Sundays, and holidays) the constant volume feed transports a reduced poundage of solids, because the mixed liquor contains less solids. Coincident with the low suspended solids loading entering the sewage plant are minimum dry weather flows,

which from a hydraulic standpoint tend to reduce the volume of feed passing over in influent gates to the concentrators; the gates thereby act as flat weirs.

There have been several occasions in which considerable difficulty was experienced by engineers in obtaining a clear understanding of these relationships. However, it is only necessary to recall that in a single dry weather day the hourly variation of suspended solids is several hundred per cent and that the low night flows are also low in suspended matter. Also, there is a definite but slight change in the hydraulic elevation of the activated sludge tank system between high and low flow.

Effect on Final Settling Tank Capacity

The question may be properly asked: "How can the Easterly plant afford to remove two of the 16 final settling tanks from service for the purpose of sludge concentration?" It has been previously stated that an overflow rate of 400 g.p.d. per square foot is used for the control of clarifiers converted to concentration tanks. The normal overflow rate of the final settling tanks is approximately 800 g.p.d. per square foot. The effectiveness of the two tanks in regard to the production of effuent is equivalent to one of the 14 normally operated final settling tanks. The character of the concentration overflow is considered very good, averaging 26 p.p.m. of suspended solids for the past six years. The actual reduction in final settling capacity due to the conversion was 6.25 per cent.

The use of chlorine in connection with thickening has been practiced by several New York City plants, and others. Donaldson (2) considers chlorination a helpful step during the summer months, or on occasions when the settling characteristics of the sludge are not good. The application of chlorine to the feed within the range of 5 to 33 p.p.m. adversely affected the thickening process at Cleveland. With 33 p.p.m. of chlorine a definite milky appearance was imparted to the overflow, indicating a dispersion of organic matter. In general, chlorine was not helpful because the settling

TABLE I.—Concentration of Activated Sludge Mixed Liquor in Two 112-ft. Diameter Dorr Clarifiers, Cleveland Easterly Plant

Year	Susp. Solids (p.p.m.)			Flow (m.g.d.)			Overflow (g.p.d./sq. ft.)	Sludge Index	Solids Treated (tons/day)
	Feed	Underflow	Overflow	Feed	Underflow	Overflow			
1944	2,110	28,000	201.3[1]	5.99	0.46	5.53	296	100	53.77
1945	1,510	26,000[2]	23.3	8.72	0.46	8.26	419	88	49.94
1946	1,485	23,300[2]	20.2	9.07	0.57	8.50	435	91	55.45
1947	1,892	26,500[2]	29.1	9.25	0.65	8.60	440	98	71.90
1948	1,440	24,200[2]	25.7	10.25	0.60	9.65	492	100	60.60
1949	1,509	15,100	29.4	6.92	0.68	6.24	332	99	42.85
1950	1,532	31,000	29.1	9.09	0.47	8.62	436	99	60.82
Total	11,478	174,100	156.8	59.29	3.89	55.40	2,850	675	395.33
Max.	2,110	31,000	201.3	10.25	0.68	9.65	492	100	71.90
Min.	1,440	15,100	20.2	5.99	0.46	5.53	296	88	42.85
Av.	1,640	24,870	26.1	8.47	0.56	7.91	407	96	56.48

[1] Not included in total and average; sludge level controlled too high for the production of a satisfactory overflow.

[2] Computed underflow solids; thickened sludge return to primary tanks during this period. No special effort made to obtain optimum concentration.

characteristics of the activated sludge at the Easterly plant are good, as shown by the 7-year average sludge index of 96 (Table I). It is important that the thickened sludge remain fresh by daily withdrawals equal to the solids loading. High sludge levels allow decomposition to set in, causing both odors and poor quality of overflow. The 1944 record of 201 p.p.m. of suspended solids in the overflow was corrected by keeping the thickened solids to within 2 ft. of the bottom of the tanks. The presence of dissolved oxygen or nitrate is desirable so that the action and appearance is similar to that of any properly operated final settling tank.

Disposal of the thickened sludge containing 15,000 to 31,000 p.p.m. total solids has been done by two methods. During 1944, 1945, and again in 1950, thickened sludge was pumped directly to digestion tanks some 13 mi. distant. Thickened sludge was returned to the primary settling tanks for the 4-year period 1946–49. The recycling effect of activated sludge from the primary tanks back through the aeration tank system became very troublesome during the first three months of 1950. The upset condition was corrected by discontinuing the return of thickened sludge to the primary tanks. There was not sufficient detention time in the primary tank to allow the floc to reconcentrate and a considerable quantity floated through, causing overload in the aeration tanks. This experience supports Donaldson's (2) contention that "the rather common practice in smaller plants of concentrating excess activated sludge by wasting return sludge to the head of the primary tanks is not to be recommended unless the primary retention period is 2 hr. or more. Short retentions are apt to result in higher suspended solids in the effluent than in the raw sewage influent. Moreover, the septic character of the settled sewage is likely to be disturbing to the subsequent aeration process."

Conclusions

The following conclusions are based on the author's seven years of experience concerning continuous operation data on the concentration of activated sludge mixed liquor.

1. The thickening of mixed liquor is preferred to the thickening of excess activated sludge.
2. The control of solids in the activated sludge process can be done by a simple final settling tank arrangement that eliminates hourly and daily adjustment in regard to excess activated sludge. Complicated mechanical valving controls are not recommended.
3. Concentration tanks of special design, including chlorination control, were not found to be necessary at Cleveland.
4. The concentration tank overflow can be controlled so that it approaches the quality of typical plant effluent. The suspended solids need not exceed 30 p.p.m.
5. The concentration of mixed liquor in an environment of dissolved oxygen or nitrate will produce a thickened sludge containing approximately 30,000 p.p.m. of total solids on a yearly average basis.
6. Odor nuisance can be completely eliminated and no special construction is required for segregation to prevent objectionable conditions.

References

1. Bloodgood, D. E., "Concentration of Activated Sludge." *Sewage Works Jour.*, **19**, 2, 202 (Mar., 1947).
2. Goudey, R. F., Keefer, C. E., Rudolfs, W., and Donaldson, W., "Concentration of Sewage Sludge: A Symposium." *Trans.*, A.S.C.E., **110**, 1557 (1945); abs. *Sewage Works Jour.*, **17**, 1, 188 (Jan., 1945) and **18**, 6, 1238 (Nov., 1946).

DISCUSSION

By Clyde E. Kirsch

Operator, Southerly Sewage Treatment Plant, Cleveland, Ohio

The problem of satisfactory treatment of excess activated sludge has long been a cause of considerable research work in sewage treatment. The main difficulties encountered in treatment of activated sludge are caused by the voluminous nature of the sludge and by its flocculent characteristics. Activated sludge air-dries slowly, even when spread in thin layers. The sludge, when in good condition, is golden-brown and has a pleasant earthy odor. In warm weather it decomposes rapidly. It will digest by itself, but is best mixed with primary sludge for digestion purposes.

It has been shown by past attempts at further treatment of excess activated sludge that the mixing of primary sludge and waste activated sludge after their independent removal from primary and final settling tanks, respectively, is not very satisfactory. This method is not satisfactory because the volume of activated sludge is so great, as compared to the volume of primary sludge. It is important, therefore, to decrease the volume of waste activated sludge before further treatment is practical. The final treatment of activated sludge is usually digestion in heated tanks.

Common Methods

The treatment of activated sludge has usually been an adaptation of one of the following methods:

1. The return of the waste activated sludge to the influent of the primary tanks and the pumping of the resulting combined settled solids to the digestion unit.
2. The use of "picket fence" type thickeners with the "thickened" sludge going to the digesters and the separated liquor going to the influent of primary tanks.
3. The use of centrifuges with the centrifuged solids going to the digesters and the separated liquor going to the primary tanks for further treatment.

These methods have their faults, however. In wasting the excess activated sludge to the primary tanks under normal flow conditions, more sludge withdrawals daily are required to prevent the lighter, more buoyant settled solids from coming to the surface of the tank. This condition is not as prevalent when only the primary sludge has to be considered. In combined sewage systems during storm flows, the detention time in the primary tanks is reduced at times by more than 50 per cent. Consequently, a greater portion of the solids is carried out with the effluent of the primary tanks. This naturally recycles the activated sludge solids through the activation unit again, resulting in double, or even triple, treatment. In decreasing the sedimentation time during storm flows, the resulting solids concentration of the mixed settled solids of the primary sludge and activated sludge would be poorer than normally expected. Consequently, a poor mixture would be forthcoming for further digestion purposes.

Concentration of waste activated sludge by "picket fence" type thickener or by centrifuging has in many cases resulted in solids concentrations of as high as 4 per cent. It is necessary, however, that motor-driven equipment be used in both of these processes. The cost of installation, power supplied, and maintenance is increased. Therefore, if the concen-

tration of solids experienced by the use of either of these methods is not sufficiently greater than the concentration of solids experienced by sedimentation only, the added cost factor must be considered. Thickening, or flocculation, by these processes requires from 6 to 12 hr., and the tank may have to be chlorinated to retard decomposition.

Cleveland's Easterly and Southerly plants both use rather unusual procedures for concentration of waste activated sludge. The Easterly plant makes use of two of its final clarifiers to concentrate the activated sludge or, more correctly, the mixed liquor. The resulting concentrate is pumped either separately or mixed with the primary sludge through a 13-mi. force main to the Southerly plant for final digestion. The Easterly plant's process has already been fully explained by Messrs. Wirts and Ausflug; therefore, the balance of this discussion deals with the concentration of activated sludge at the Southerly plant.

Southerly Plant Method

The Southerly plant has Imhoff tanks for primary sedimentation. The digestion chambers of these tanks would be overloaded if the waste activated sludge were added to the tank influent. In the operation of the Imhoff tanks it has been found advantageous to keep the activated sludge out of them and to concentrate the waste activated sludge produced at the Southerly plant in Dortmund tanks (Figure 2), digesting the concentrated sludge along with Easterly's concentrated mixed liquor and primary sludge in Southerly's digestion units. The meters for the various sludge flows are shown in Figure 3.

The Dortmund tanks at the Southerly plant are 26 ft. in diameter for the top 4.5 ft. of depth; they are then conical in section and taper to a diameter of 1.5 ft. at the bottom drawoff valve. The conical section has a vertical depth of 21 ft. and the total capacity of each tank is 47,900 gal. Nor-

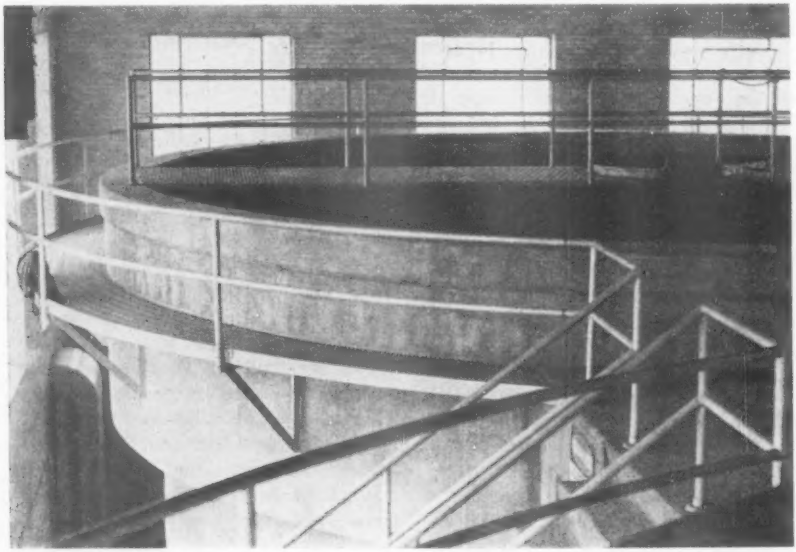

FIGURE 2.—Dortmund tanks for waste activated sludge concentration at Cleveland's Southerly sewage treatment plant are enclosed in separate building.

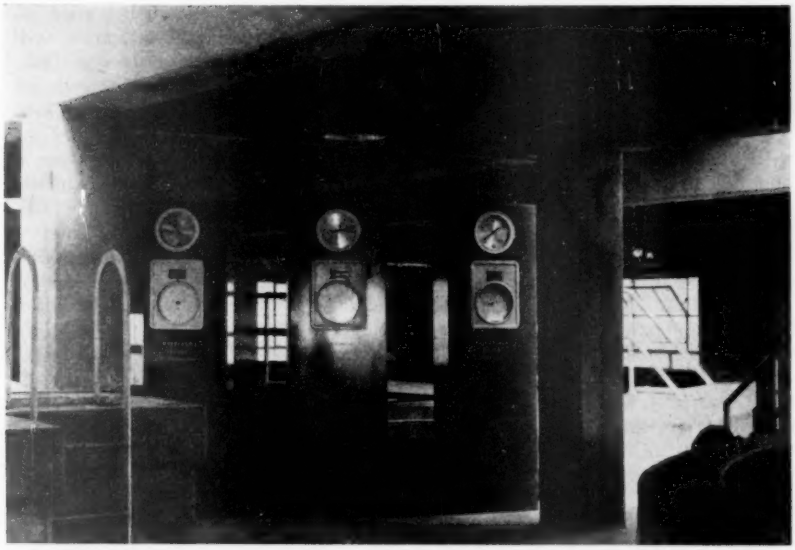

FIGURE 3.—Flow meters in sludge concentration building at Cleveland Southerly sewage treatment plant register Easterly plant sludge influent and withdrawal, as well as Southerly plant's excess sludge.

mally, two Dortmund tanks are filled with waste activated sludge twice a day—usually at 8:00 A.M. and 8:00 P.M. The average sedimentation time for concentration is 7½ hr. for the total of 191,960 gal. concentrated each day. A summary of results of concentration of waste activated sludge for the year 1950 shows that the reduction in gallonage was 37.9 per cent, with 98.0 per cent of the solids retained. The dry solids content was raised from 1.72 per cent in the waste activated sludge to 2.70 per cent in the concentrate, an increase of 57.3 per cent in solids.

Standard operating procedure for emptying the Dortmund tanks is as follows: Because the lower portion of a Dortmund tank is conical in section and the drawoff valve is at the extreme bottom of the conical section, the concentrated solids are drawn off first. The concentrated solids are allowed to flow by gravity; if the hydrostatic head is not sufficient, pumps are used to transfer the solids to the sludge digestion units. Samples are taken for laboratory analysis on a predetermined time basis. The attendant on the job takes samples at the bottom of the tank and when the physical characteristics of the sludge show that

TABLE I.—Results of Pilot Plant Study of Activated Sludge Concentration by Sedimentation Only (Per Cent Maximum Settling)[1]

Solids (%)	Settling Time (hr.)					
	1	2	3	4	5	6
0.4	86	87	88	88	88	90
0.7	80	82	84	85	85	85
1.1	47	60	68	70	73	74
1.5	29	50	60	64	67	68
1.5	13	29	40	50	53	57
1.6	15	35	50	54	58	61
1.6	11	22	33	41	46	51
1.7	15	30	41	49	53	56
2.2	5	11	20	27	36	41

[1] As measured by percentage of original volume occupied by clear liquor at indicated times.

it is too thin for practical digestion purposes, the flow to the digestion unit is stopped. The balance of the contents is pumped to a higher elevation and allowed to flow by gravity to the head of the plant, where it mixes with the incoming sewage. This pumping of supernatant liquor is also sampled on a predetermined time basis for laboratory analysis. Both Dortmund tanks are emptied simultaneously, the entire procedure taking approximately 2½ hr. Filling of the tanks with waste activated sludge for concentration takes about 2 hr. The combination of charging plus discharging time, plus the actual sedimentation time, accounts for the 12-hr. interval between fillings of Dortmund tanks. There are times when good operation of the sludge activation unit requires operation of only one Dortmund tank in order that the sludge blanket in the final clarifiers be kept at normal levels.

The 7½-hr. concentration time is used because it closely approximates the necessary removal of waste activated sludge produced in the activation unit under present loading conditions. However, it has been determined by laboratory experimentation on pilot plant scale that the full 7½-hr. period is not a prime requisite for good concentration results (Table I). An optimum minimum sedimentation time of 3 to 4 hr. has been found satisfactory for concentration purposes.

WEST VIRGINIA'S FIRST OPERATORS' SHORT COURSE

On June 11–14, 1951, the Division of Sanitary Engineering, West Virginia State Department of Health, and the Department of Civil Engineering and the Mining and Industrial Extension Department of the School of Mines, West Virginia University, jointly sponsored a short course for sewage plant operators at West Virginia University, Morgantown, W. Va. The short course had been recommended by the West Virginia Sewage and Industrial Wastes Association for the past couple of years.

The short course consisted of classes on sewage terms and calculations, sewage characteristics, sampling procedures, primary and secondary treatment, sludge collection and digestion, maintenance and operation of chlorinators, maintenance of sewage treatment plants, reports and records, stream sanitation, and demonstration and practice in setting up and running laboratory tests.

Highlights of the short course included a dinner at "The Oaks" with Edwin R. Cotton, Director, Interstate Commission on Potomac River Basin, presenting a paper entitled "Progress in Sewage Treatment and Stream Sanitation" and an inspection trip to the Carolina sewage treatment plant, Carolina, West Virginia. Certificates of attendance were given to 13 West Virginia operators at the close of the sessions.

TRICKLING FILTER PERFORMANCE AT INTERMEDIATE LOADING RATES *

By G. R. Grantham

The trickling filter has long been a standard secondary treatment unit for the treatment of organic pollutional loads. In the interests of economy, considerable research work has been conducted on the increased loading of these units. The majority of the work has been done on the so-called high-rate filter, which depends upon recirculation and/or special loading devices for increased contact time. Reports of performance for increased loading on standard-rate filters are few, but experiments by Levine *et al.* (5) and by Keefer and Kratz (3) are notable contributions. Others (1)(6) have reported results of instances where standard rates have been exceeded due to operation at higher than design loadings. In every instance, the conclusion was reached that the ability of the standard-rate filter to perform satisfactorily under increased loading has been underestimated.

Experimental Methods

Sanitary engineering research at the University of Florida has been identified with the experimentation with conventional sewage treatment units to determine how present-day design criteria may be modified to make best use of Florida operating conditions. This experiment, one of a series being conducted utilizing the facilities described by Williams and Lee (10) and others (4), involved the loading of a 6-ft. deep slag-filled filter at hydraulic rates of loading between 5.0 and 20.0 m.g.a.d. with no recirculation. Settled domestic sewage was applied continuously to the bed by a two-arm reaction-driven rotary distributor of conventional design rotating 5 to 10 r.p.m. Constant flow to the filter throughout 24 hr. each day was maintained by means of weirs and gates. Flow was measured by a V-notch weir. Due to the low flows available at night, the area of filter used was decreased as the hydraulic rate was increased in order to maintain the desired loading. This was done by plugging the nozzles of the distributor as necessary. The question that such practice would allow some horizontal distribution into unused areas was dispelled by removing several yards of stone to a depth of 4 ft. for inspection. There was very little evidence of lateral distribution. Actual areas and total flows used are recorded in Table I.

Continuous sampling devices were used. Samples were collected of the applied sewage, at the 2-ft. level, and at the 4-ft. level. Samples of the settled filter effluent were collected twice daily and refrigerated until the daily composite could be made. Usually the composite was made immediately following collection of the second 12-hr. sample, and analyses for B.O.D., suspended solids, and nitrogen fractions were then made according to "Standard Methods" (7). Direct nesslerization was used in ammonia nitrogen determinations and the phenoldisulfonic acid method was used in determination of nitrate nitrogen.

Samples were collected, for the most part, during the fall, winter, and spring seasons. No particularly cold weather was experienced during the

* A contribution from the University of Florida Engineering and Industrial Experiment Station, Gainesville, Fla.

TABLE I.—Conditions of the Tests

Hydraulic loading (m.g.a.d.)	5.0	7.5	7.5	8.3	10.0	12.5	15.0	17.5	20.0	14.6[1]
Flow (1,000 g.p.d.)	100	150	100	150	150	150	150	150	150	420
Area utilized (cu. ft.)	871	871	581	784	653	523	436	373	327	1,255
Av. effluent temp. (°F.)	77	77	80	75	73	77	79	73	72	72
No. samples analyzed	17	22	29	19	27	26	24	25	22	29
Date of test from:	3/9/48	5/12/48	7/1/49	12/8/48	3/2/49	3/29/49	4/26/49	11/2/49	2/28/50	11/3/50
to:	4/9/48	11/19/48	10/14/49	2/3/49	3/28/49	4/24/49	5/18/49	1/13/50	3/25/50	12/15/50

[1] Supplementary test.

entire test. The dates of each test, the number of samples taken, and the average filter effluent temperature are recorded in Table I. Analytical data are summarized in Tables II, III, and IV. (Note—A supplementary test using the entire 40-ft. diameter filter and the entire daily flow was conducted after the series herein described. Data for this test are recorded in Tables I to IV, inclusive.)

In order to determine the degree of treatment afforded by only 2-ft. and 4-ft. deep filters plus settling, 5-gal. composite samples at each depth were collected, agitated sufficiently to obtain an unsettled sample, then allowed to settle for 1 hr. in the 5-gal. container. The upper portion was then siphoned off for analysis. The 6-ft. sample was also handled in this manner to determine the effect of better settling conditions than were provided on a plant scale. Results of these analyses are contained in Tables II and III. Nitrogen analyses also were run, but the results were not materially different from the unsettled

TABLE II.—Average B.O.D. Data

B.O.D.	Hydraulic Loading (m.g.a.d.)									
	5.0	7.5	7.5	8.3	10.0	12.5	15.0	17.5	20.0	14.6[1]
Applied (p.p.m.)	196	132	112	120	151	144	178	183	197	166
2-ft. level (p.p.m.)	97	115	72	81	151	149	141	143	129	130
Reduction (%)	51	10	33	35	−2	−5	22	21	32	21
4-ft. level (p.p.m.)	48	74	38	59	90	80	79	97	69	84
Reduction (%)	76	43	66	53	39	43	57	46	65	48
6-ft. level (p.p.m.)	49	40	23	46	49	53	53	56	39	65
Reduction (%)	75	65	78	65	70	64	70	70	80	61
Settled effluent (p.p.m.)	43	30	13	23	24	25	25	38	23	53
Reduction (%)	77	73	88	80	87	83	86	79	88	68
2-ft. level sett. (p.p.m.)	—	—	41	—	—	59	80	93	77	106
Reduction (%)	—	—	63	—	—	57	56	48	60	36
4-ft. level sett. (p.p.m.)	—	—	20	—	—	22	34	64	39	59
Reduction (%)	—	—	81	—	—	84	81	64	80	68
6-ft. level sett. (p.p.m.)	—	—	13	—	—	15	20	32	23	51
Reduction (%)	—	—	88	—	—	90	88	83	88	69
Loading:										
Lb./acre-ft./day	1,358	1,375	1,167	1,390	2,100	2,500	3,700	4,431	5,470	3,350
Lb./cu. yd./day	0.84	0.85	0.72	0.86	1.30	1.55	2.30	2.88	3.39	2.06
Lb./sq. ft./day[2]	0.19	0.19	0.16	0.19	0.29	0.34	0.51	0.61	0.75	0.46
Rate of oxidation, K	0.245	0.105	0.188	0.113	0.089	0.153	0.186	0.075	0.179	0.190
Limit of oxidation, L	0.792	0.917	0.905	0.843	1.22	0.900	0.812	1.16	0.920	0.708
Lag depth factor, b (ft.)	0.0	1.6	0.9	0.3	2.1	2.2	1.5	1.0	1.0	1.3
B.O.D. satisfied (lb./cu. ft./day)	0.65	0.62	0.63	0.69	1.13	1.29	1.98	2.28	2.78	1.38

[1] Supplementary test.
[2] Of 6-ft. deep filter.

results and are not included. This indicates that most of the nitrogen compounds are in solution or suspension. Collection of this information did not commence until the series was about half completed.

Discussion of Results

B.O.D. loadings varied from 1,167 to 5,470 lb. per acre-foot daily. These loadings are considerably higher than the design loadings as set forth by the U. S. Army for design of service plants. Throughout the entire range of loading the efficiency of this unit in reduction of 5-day B.O.D. applied did not decrease. This is illustrated in Figure 1, in which B.O.D. loading is plotted against B.O.D. satisfied. A line drawn through the plotted points does not indicate a tendency to curve downward at higher loadings. The line shown is the 82 per cent efficiency line. This does not mean that the quality of the effluent does not decrease as loading is increased, because at the higher loadings nitrification had virtually ceased.

In most instances the B.O.D. removals followed the hypothesis presented by Velz (9). Values of the rate of oxidation, K, and the limit of oxidization, L, were computed from the average per cent reductions by the method of Thomas (8) and are shown in Table II. No obvious relationship is demonstrated concerning dependence of K and L upon organic or hydraulic loading in this test.

In two instances (10 and 17.5 m.g.a.d.), the data in this test did not follow the Velz law. Attempts to fit that relationship to the data of these runs resulted in impossible values of L, the limit of oxidization. In both cases, a straight line relationship between per cent B.O.D. reduction and depth was approximated. No reason for this is apparent.

It was found that a curve of monomolecular shape drawn through the plotted points of per cent reduction at the various depths intersected the zero per cent reduction line at points varying from the surface of the filter to a depth of 2.2 ft. The values for

TABLE III.—Average Suspended Solids Data

Suspended Solids	Hydraulic Loading (m.g.a.d.)									
	5.0	7.5	7.5	8.3	10.0	12.5	15.0	17.5	20.0	14.6[1]
Applied (p.p.m.)	—	62	—	64	65	49	68	95	98	81
2-ft. level (p.p.m.)	—	130	—	104	124	96	97	75	97	112
Reduction (%)	—	−110	—	−63	−91	−95	−43	21	1	−38
4-ft. level (p.p.m.)	—	77	—	97	103	77	76	80	74	96
Reduction (%)	—	−24	—	−52	−59	−57	−12	16	25	−19
6-ft. level (p.p.m.)	—	46	—	58	45	51	63	66	61	76
Reduction (%)	—	26	—	9	31	−4	7	31	38	6
Settled effluent (p.p.m.)	—	36	—	31	34	27	26	21	28	51
Reduction (%)	—	42	—	52	48	45	62	78	71	37
Detention time (min.)[2]	—	90	—	90	90	90	90	90	90	32
2-ft. level, sett. (p.p.m.)	—	—	—	—	—	17	21	41	42	57
Reduction (%)	—	—	—	—	—	65	69	57	57	30
4-ft. level, sett. (p.p.m.)	—	—	—	—	—	8	16	26	23	35
Reduction (%)	—	—	—	—	—	84	77	73	77	57
6-ft. level, sett. (p.p.m.)	—	—	—	—	—	8	8	12	16	30
Reduction (%)	—	—	—	—	—	84	88	87	84	63

[1] Supplementary test.
[2] Detention time in secondary settling tank.

each loading are shown as lag depth, b, in Table II. The lag depth values tend to increase as the hydraulic loading is increased to 12.5 m.g.a.d., and decrease thereafter. This is probably the transition zone between standard-rate and high-rate operation, so that there is an indication of possible clogging in that range of loading. Actually, the filter did not clog, but in that range of hydraulic loading in this test it was observed that a second or two was required for the applied sewage to disappear after passage of the distributor arm, as compared to instantaneous disappearance at all other loading ranges. Keefer and Kratz (3) and Levine *et al.* (5) report no clogging. Organic loadings in this test for this range of hydraulic loading are higher than reported by them, as evidenced by Figure 2, and it variously speculated as the range of loading where operational trouble would be encountered. The build-up of organic material in the top layers of the bed apparently exceeds the rate of biological utilization and the hydraulic rate is not yet sufficient to wash the excess accumulation through,

TABLE IV.—Average Nitrogen Data

Nitrogen	Hydraulic Loading (m.g.a.d.)									
	5.0	7.5	7.5	8.3	10.0	12.5	15.0	17.5	20.0	14.6[1]
Applied (p.p.m.):										
Org. N	—	16.6	9.0	14.3	15.4	11.0	14.9	6.4	4.7	15.1
NH_3-N	—	18.1	15.4	19.5	20.2	16.3	18.8	32.7	32.9	24.9
NO_2-N	—	0.024	0.018	0.022	0.025	0.031	0.035	0.024	0.039	0.057
NO_3-N	—	0.08	0.05	0.09	0.04	0.09	0.05	0.06	0.14	0.19
2-ft. level (p.p.m.):										
Org. N	—	18.8	9.0	16.8	18.2	14.1	17.7	10.9	8.6	15.1
NH_3-N	—	16.6	13.2	17.6	21.4	16.1	18.8	29.2	28.2	27.9
NO_2-N	—	0.133	0.201	0.045	0.028	0.047	0.064	0.046	0.037	0.062
NO_3-N	—	0.14	0.38	0.08	0.06	0.10	0.10	0.05	0.15	0.22
4-ft. level (p.p.m.):										
Org. N	—	13.3	5.8	14.6	18.5	13.7	14.5	7.9	5.7	15.1
NH_3-N	—	13.3	9.4	14.9	19.8	15.4	16.0	29.2	30.2	27.9
NO_2-N	—	1.074	0.812	1.079	0.074	0.234	0.243	0.156	0.134	0.118
NO_3-N	—	1.51	2.62	0.52	0.06	0.27	0.39	0.36	0.23	0.22
6-ft. level (p.p.m.):										
Org. N	—	8.5	4.5	11.0	13.9	12.5	12.5	7.1	5.9	11.9
NH_3-N	—	9.0	5.0	11.7	18.2	14.0	15.6	26.9	28.1	27.1
NO_2-N	—	1.034	0.894	1.237	0.190	0.247	0.194	0.256	0.125	0.188
NO_3-N	—	7.57	5.10	4.11	0.26	0.45	0.29	0.29	0.28	0.29
Settled effluent (p.p.m.):										
Org. N	—	7.3	4.5	7.6	12.8	8.53	9.57	5.2	4.9	10.2
NH_3-N	—	9.2	11.3	10.4	16.0	12.9	14.3	25.2	26.7	25.4
NO_2-N	—	1.204	1.082	1.197	0.204	0.371	0.263	0.206	0.172	0.352
NO_3-N	—	8.79	3.58	5.08	0.54	1.47	0.55	0.65	0.31	0.80
Nitrification (%):										
Applied	—	0.26	0.27	0.31	0.17	0.42	0.23	0.21	0.45	0.59
2-ft. level	—	0.68	2.38	0.35	0.21	0.45	0.41	0.22	0.49	0.62
4-ft. level	—	8.12	17.6	4.45	0.31	1.54	1.87	1.29	0.93	0.73
6-ft. level	—	32.2	37.6	18.2	1.27	2.38	1.56	1.43	1.11	1.12
Settled effl.	—	36.8	21.7	25.0	1.78	7.68	3.08	2.60	1.39	2.94
Rate of nitrification, K_n	—	0.305	0.229	0.153	—	0.196	—	—	—	—
Limit of nitrification, N	—	0.400	0.506	0.320	—	0.117	—	—	—	—
Lag depth, a (ft.)	—	3.7	3.3	3.8	5.0	5.5	—	—	—	5.3

[1] Supplementary test.

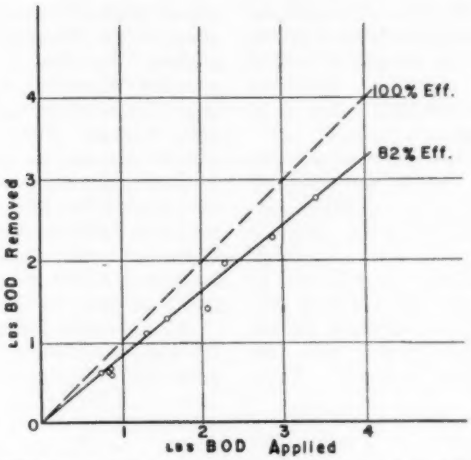

FIGURE 1.—B.O.D. removals at various rates of application.

is predicted that, for heavy organic loading at hydraulic loadings in this range (10 to 12.5 m.g.a.d.), clogging will result.

It is believed that low night flows caused the low efficiency in the supplementary test where the entire plant flow and entire filter area were used. For as many as six consecutive hours starting at midnight the distributor did not rotate. Observations made during this test and elsewhere have caused the writer to conclude that continuous application of sewage by

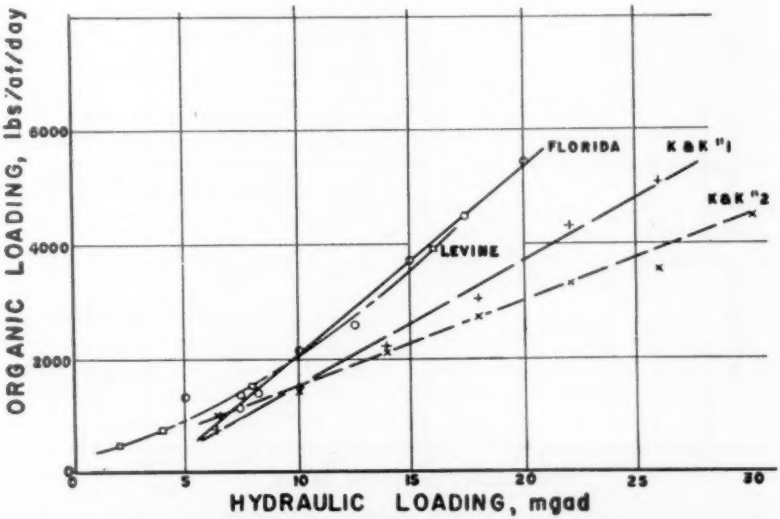

FIGURE 2.—Comparative hydraulic and organic loadings.

reaction-driven distributors is not possible at hydraulic loading rates below 5 m.g.a.d. Special designs of rather simple nature could be employed where night flows become so low as to cause this trouble.

That part of the action of a trickling filter is to change colloidal and soluble solid matter to settleable matter is demonstrated when samples from the 2-ft., 4-ft., and 6-ft. levels were settled. When the difference in per cent reduction of B.O.D. in the settled and unsettled sample is plotted against hydraulic loading rate, the curves of Figure 3 result. These curves show the degree of treatment afforded by flocculating action plus settling. The effect is maximum at the so-called "transition zone" and in the upper layers of the bed. It would appear that the ability of the bed to oxidize organic matter falls behind its ability to remove this matter from the colloidal or soluble form as the hydraulic loading is increased; but at higher hydraulic loadings, the washing action distributes the effect more nearly throughout the filter bed.

The suspended solids data in Table III also demonstrate this flocculating property. Suspended solids increased

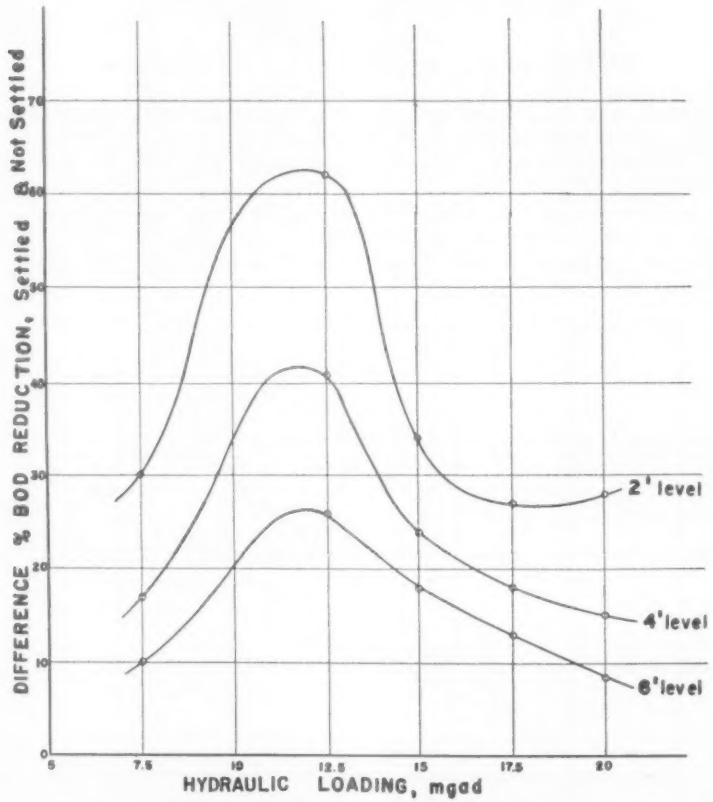

FIGURE 3.—Removal by combined flocculation and sedimentation, at various levels; defined by the difference in total removal between settled and unsettled samples.

in the upper bed levels and in the hydraulic loading range between 7.5 and 15 m.g.a.d. The solids were settleable, as is shown by the difference in suspended solids in the settled and unsettled portions of the same sample. Suspended solids in the settled effluent during the test ranged between 21 and 36 p.p.m. The effectiveness of the secondary settling unit used was not particularly good, as is evidenced by the considerably higher per cent reductions in the filter effluent settled for 1 hr. in a 5-gal. carboy.

The degree to which nitrification was afforded by this filter decreased as the organic and hydraulic loading increased. This result is comparable to that of Keefer and Kratz (3) and Levine *et al.* (5). The values for rate of nitrification, K_n; limit of nitrification, N; and the lag depth factor, a, as proposed by the writer (2), also show this fact. Values of K_n and N were computed using the method of Thomas (8). The per cent nitrification was computed by dividing 80 per cent of the NO_2-N plus the NO_3-N in a sample by the total nitrogen in that sample. The highest loading at which a perceptible nitrification stage appeared in the regular test was at 2,500 lb. per acre-foot daily and at 12.5 m.g.a.d.

The effect of temperature on operation of trickling filters under conditions in this test is not clearly shown, because the temperature of the sewage remained nearly constant throughout the test. Mild air temperatures, except for scattered low-temperature periods of short duration, were experienced. The only really cold weather occurred during the last eight days of the supplementary test. During that period, the average filter effluent temperature dropped from 75° to 67° F., the reduction in applied B.O.D. dropped from 70.7 per cent to 64.7 per cent, and the nitrification of the effluent dropped from 3.3 per cent to 3.1 per cent. The average air temperature decreased from 64° to 50° F. during this period.

Conclusions

The following conclusions are drawn from the results of this test:

1. A standard-rate trickling filter operated under certain conditions of organic and hydraulic overload can be expected to reduce B.O.D. with little or no decrease in efficiency and without operational difficulties. Certain combinations of high organic loading and hydraulic loading may cause a tendency to clog the bed. Organic loadings over 2,500 lb. per acre-foot per day at hydraulic loadings of 10 to 12.5 m.g.a.d. should be avoided.

2. Nitrification of the filter effluent decreases as the organic and hydraulic loading increases. It is in this manifestation that the effluent quality decreases with increased loadings.

3. Reasonable suspended solids concentration in the settled effluent was obtained at all ranges of loading used in this test.

4. Considerable B.O.D. can be removed at 2-ft. and 4-ft. levels in the range of loadings employed by providing settling of effluents from those levels. The action is that of flocculation as well as oxidation, with the former predominant at shallow levels and in the loading range where clogging may be anticipated.

5. No conclusion is possible as to the effect of temperature on the results obtained, due to mild temperatures experienced throughout the test.

Acknowledgments

Appreciation is due Professor C. D. Williams, who suggested the need of this kind of test, and to Professor Earle B. Phelps, who acted as consultant during the entire test. Analytical work was performed, in part, by Marie Woodley, Emily King, and Richard

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References

1. Childs, J. A., and Schroepfer, G. S., "Trickling Filter Loadings." *Civil Eng.*, **1**, 1391 (1931).
2. Grantham, G. R., Phelps, E. B., Calaway, W. T., and Emerson, D. L., Jr., "Progress Report on Trickling Filter Studies." THIS JOURNAL, **22**, 7, 867 (July, 1950).
3. Keefer, C. E., and Kratz, H., Jr., "Experiments with High-Rate Trickling Filters at Baltimore." *Sewage Works Jour.*, **12**, 3, 477 (May, 1940).
4. Kiker, J. E., *et al.*, "Sewage Treatment Research at the University of Florida." Technical Paper No. 24, Florida Eng. and Ind. Expt. Sta. (Jan., 1949).
5. Levine, M., Luebbers, R., Galligan, W. E., and Vaughn, R., "Observations on Ceramic Filter Media and High Rates of Filtration." *Sewage Works Jour.*, **8**, 5, 701 (Sept., 1936).
6. "Sewage Treatment at Military Installations." NRC Committee Report. *Sewage Works Jour.*, **18**, 5, 794 (Sept., 1946).
7. "Standard Methods for Analysis of Water and Sewage." 9th Ed. Am. Pub. Health Assn., New York, N. Y. (1946).
8. Thomas, H. A., Jr., "'Slope' Method of Evaluating the Constants of the First-Stage B.O.D. Curve." *Sewage Works Jour.*, **9**, 3, 425 (May, 1937).
9. Velz, C. J., "A Basic Law for the Performance of Biological Filters." *Sewage Works Jour.*, **20**, 4, 607 (July, 1948).
10. Williams, C. D., and Lee, D. B., "Sewage Treatment Research Plants Study Special Florida Conditions." *Civil Eng.*, **19**, 4, 244 (1949).

EFFECTS OF SEWAGE ON CATTLE AND GARBAGE ON HOGS *

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Removal of the waste products of community life is an obligation of the local government. Not only sewage, but also all refuse (garbage and rubbish) must be removed regularly from the individual premises to maintain a clean and sanitary environment. There is always present a desire to make waste disposal services self-supporting, but this will seldom, if ever, be accomplished. Sewage and refuse disposal services are essentially scavenger in nature. From them, in certain cases, some minor returns may be obtained, but usually they are an expense item in municipal budgets. This desire to make waste disposal services self-supporting presents problems in disease control. Some of these problems will be considered in the following discussion.

Public health workers are in agreement that certain human diseases which may originate in filth and decaying matter are transmitted by an intermediary acting strictly as a carrier or as a host. In such a classification an animal (rat, mouse, dog, cat, chicken), an insect (fly, flea, mosquito, bedbug, roach, tick), a mollusk (oyster, clam, snail), or some other form of animal life is recognized as playing a part in the disease picture. Some of these intermediary hosts or carriers, such as the mosquito in malaria and yellow fever and the louse in typhus fever, are recognized and procedures have been developed for protection against them. However, there are others which have not received so much attention.

Smith (1) says: "Since there is no clear line to be drawn between the diseases of man and the higher warm-blooded animals, the time to regard human diseases as something apart closed with the studies of Pasteur and Koch. Today every pathological disturbance in animals is being examined with care to bring to the surface the means to interpret those conditions in human diseases still obscurely understood."

Not too much consideration has been given to the effects of the waste products of man on these intermediate hosts. This paper considers, therefore, the effect of sewage and sewage plant effluents on cattle and hogs and the feeding of garbage to hogs.

Irrigation and Industrial Uses of Sewage

Sewage and sewage plant effluents have been and still are widely used in some countries for irrigation purposes and are receiving increasing attention in this country for irrigation. The discharge of sewage and sewage plant effluents to receiving streams always presents problems with respect to their effect on the stream and to subsequent uses of the water of the stream. The degree of treatment required must be based upon the subsequent use of the stream if the greatest social and economic advantages are to be realized. Sewage treatment plant effluents are now being used by some industries for process and cooling purposes. More

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such use can be expected in the future as available water supplies decrease.

Possibility of Disease Transmission by Sewage

The possibility of diseases being spread to animals having access to raw sewage and sewage plant effluents has been brought to the attention of sanitary engineers in many instances as a result of lawsuits against municipalities by stock owners, who have claimed that the health of their animals was impaired through contact with the sewage or with the effluents from sewage disposal plants. Some research has been done and reports have been written discussing this problem.

There are many diseases common to both man and animals that may be transmitted directly or indirectly from one host species to another. In cattle these diseases include bovine tuberculosis, anthrax, malta or undulant fever, foot and mouth disease, actinomycosis, tapeworm, etc. Another hazard that has to be considered is the effect of toxic wastes upon cattle having access to sewage and sewage plant effluents. Sewage containing industrial wastes and sewage plant effluents where various chemicals are used as part of the treatment would require special consideration.

Experiments with Cattle

In one experiment reported by Minett, Woolridge, and Sheather (2), three healthy cattle were allowed during a period of 21 months to consume water containing human sewage. During the experiment a cow in milk consumed 5,146 gal. of sewage effluent and for 11 months the animal drank nothing but undiluted sewage effluent. A dry cow and a yearling consumed 916 and 767 gal. of sewage effluent, respectively; this included 579 and 477 gal., respectively, of effluent diluted with water and 357 and 290 gal., respectively, of sewage before final purification. The animals gave no sign that the fluid was distasteful to them; they thrived normally and maintained or increased their weight; the milking cow gave birth, at time, to a healthy calf while under experiment and during the subsequent fourth lactation her milk yield reached 1.8 gal. daily.

The authors drew the following conclusions: The experiment gave no support to the suggestion that domestic sewage contains constituents which are poisonous or injurious to cattle. There is, therefore, no real reason for the belief that any such condition as sewage poisoning exists. This inevitably forces the conclusion that the symptoms shown by cattle in alleged cases of sewage poisoning are due to other causes.

Beltsville Experiments

Crawford and Frank (3) report a series of experiments conducted at Beltsville (Md.) Research Center by the Animal Disease Station, Bureau of Animal Industry, U. S. Department of Agriculture. The tests were made to determine the effect of raw sewage, treatment plant effluent, and sludge on swine and of plant effluent on a group of bovine animals due to disease-producing bacteria or viruses that might be present in any of these elements.

The swine tests were conducted as follows: Eighteen healthy swine, weighing between 45 and 85 lb. each, shown by test to be free from tuberculosis and brucellosis, were divided into three groups of six animals each. Six hog pens were cleaned and disinfected and three swine were placed in each pen. Incoming sewage and sewage plant effluent were collected in sterile 5-gal. containers three times a week and sludge was obtained about every six weeks. For a period of six months, on Mondays, Wednesdays, and Fridays 5 gal. of incoming sewage were mixed with bran and fed to swine in pens Number 1 and 2, and 5 gal. of effluent were mixed with bran and fed to swine in pens Number 3 and 4. Two quarts of sludge were mixed with bran and

water and fed three times weekly to swine in pens Number 5 and 6. During the six-month period each swine in group 1 received approximately 67.5 gal. of incoming sewage; each swine in group 2, approximately 67.5 gal. of effluent. Only two batches of sludge were provided, so only about 20 feedings of sludge were made to the swine in group 3.

During the course of the experiment the swine gained weight normally and at no time during the period of feeding did any of these animals show loss of condition or any indication of disease. Three tuberculin tests were made of the swine during the feeding period and another six months later; none showed a reaction indicative of infection. To allow for the subsequent development of any disease condition, all animals were kept in the same pens for a further period of six months. All remained uniformly well during this period. The swine were then killed and careful post-mortem examinations were made of each carcass. No evidence of disease was observed. Samples of blood from each swine at the time of slaughter were tested for brucellosis, but none showed a positive reaction.

Concurrently with the swine experiment, bovine animals were given sewage effluent to drink. Two cows and two yearling steers, previously proved by tests to be free from tuberculosis and brucellosis, were placed in a field remote from other animals. Each cow had a week-old calf by her side. For six months, 15 gal. of plant effluent were obtained on Mondays, Wednesdays, and Fridays and emptied into the water trough in the field where the cattle were kept. No other fluid was provided until each batch of sewage effluent was drunk. None of the animals in the experiment manifested an unwillingness to drink the sewage effluent. A total of 1,215 gal. of effluent was fed the animals, most of which was drunk by the four adult animals. It was estimated that each adult received in the neighborhood of 275 gal. of effluent. During the summer months each animal lost some weight; whether this was due to the summer heat and a relatively poor diet is not known. At no time, however, did they show any indication of sickness or loss of appetite. Three tuberculin tests made during the experiment and one six months after on each of the cattle were negative. The four older cattle were killed and a careful post-mortem examination made of each. These animals were in good condition and showed no evidence of disease with the exception of one cow, in which calcareous, parasitic lesions were demonstrated in the intestines and liver. Subsequent injections of these concretions, after being emulsified, into guinea pigs failed to produce evidence of disease in them.

On the basis of the tests made, it was concluded by the authors that virulent bacteria are not present in sufficient concentration in the sewage plant effluent and sludge of the treatment plant at Beltsville to cause disease in susceptible animals. The plant units are a coarse bar screen, grit chambers, flocculating tanks, primary settling tanks, trickling filters, final settling tanks, glass-covered sludge drying beds, chlorinators, and chemical dry feed machines. Both pre-chlorination and post-chlorination are possible. It was not stated what the chlorine treatment consisted of during these experiments.

South African Conference

In a recent conference (1947) on "The Grazing of Cattle on Sewage Farms" (4) at Pretoria, South Africa, considerable discussion was had regarding the public health aspect of allowing cattle to graze on sewage-irrigated lands. Although the knowledge of the subject was very limited, some of the comments may be of value.

Grazing of cattle on sewage farms was a source of income to local authorities and would not be given up easily until proved to be an unsound public

health practice. Sewage farms meant a great deal to many dairymen in connection with the production of milk. It was felt that the most important public health consideration was the danger connected with dairy cows grazing on such farms, in that the udders might become infected with typhoid bacilli and spread the infection to milk. Cattle could also become infected with various types of measles and spread tapeworm infections. Other dangers are lung and other types of infection, which may or may not become communicable to humans.

It was stated by Wilson (4) that after more than 100 years of practice in sewage farm irrigation from small to colossal, no epidemic of formidable cattle or animal disease has been traced to a sewage farm. This statement is, of course, only a negative one, but failure to establish responsibility for epidemics has not been a matter of neglect, for always the sewage-irrigated farm has been watched by responsible bodies in the countries where sewage irrigation is practiced. If, then, after 100 years of sewage farming there is still no evidence of any actual epidemic being traced to such operations, in spite of many careful investigations, the conclusion is inescapable that the risks cannot be as great as would at first be supposed.

Robinson (4) stated that on the sewage farms it was observed that cattle preferred drinking effluents, even where fresh water was available. With regard to tuberculosis, the following abstract from a paper by Christiansen and Jepsen (5) is quoted:

"Waste waters from eighteen dairies were examined for the occurrence of tubercule bacilli. These bacteria were found in only one case, although the incidence of tuberculosis in the herds was high. Cattle which were pastured in fields irrigated by waste water from the dairies and which drank water from a brook receiving waste water from a dairy, were not infected. *B. tuberculosis* of the bovine type was found in samples of waste water from one out of eight rendering plants examined. Of fifteen samples of water from a brook which received waste water from a slaughter house, eight samples contained *B. tuberculosis*. In four experiments, twenty-three cows remained free from tuberculosis, although the polluted brook was their only source of water supply."

Survival of Disease Organisms

In considering the possibility of disease transmission by sewage and sewage plant effluents, many factors must be considered. The sewers of any town must receive the eggs, ova, bacteria, and viruses of almost every disease of man and domestic animal. The survival of these disease organisms is dependent upon their physiological characteristics. Some of these characteristics are the ability to form spores, the very resistant phase of bacteria; their resistance to heat and cold; their resistance to antiseptics; their ability to withstand competition with other organisms; the pressure of bacteriophages; etc. Whether they are able to cause infection depends upon other factors, some of which are loss of virulence, the presence of the sheer numbers required to become infective, the chance of being ingested by the proper host, and the resistance of the host. Many experiments have been made to determine whether various disease germs are able to survive sewage treatment processes.

Pramer and Heukelekian (6), working on the survival of tubercule bacilli in sewage treatment processes, state that these bacilli would be removed by sedimentation, chemical coagulation, and sand filtration in the same order as the removal of the organisms normally present in sewage. Higher than normal chlorine residuals are necessary to yield an effluent free of tubercule bacilli. Bacteria morphologically identical to *Myrobacterium tuberculosis* was isolated from various phases of a sanitorium treatment plant, reduction being from 1,500 per cc. in the raw sew-

age to 10 per cc. in the treatment plant effluent.

The work of Pramer and Heukelekian shows that the *B. tuberculosis* can exist in sewage and can be found in sewage plant effluent. More work is needed to determine whether cattle can be infected by the number present in such effluents, even though the cattle reported by Christiansen and Jepsen (5) did not become infected when exposed to wastes containing the bacilli. Until more information is available public health authorities will have to require as nearly complete treatment and sterilization as is possible where wastes known to have high bacterial contamination are discharged and where it is known that cattle will come in contact with them.

Garbage Feeding of Hogs

The second item to be considered is the feeding of garbage to hogs. Garbage can be disposed of by feeding it to hogs and such feeding is practiced to a large extent in the United States. At farms and isolated country houses it has been an old and common custom to use garbage for feeding hogs and chickens. Farmers have often found it profitable to collect garbage from nearby towns for this purpose. In small communities this method of disposal persists and in many large towns and cities hotel and apartment house garbage is disposed of by having it collected and fed to hogs by the individual farmer.

Garbage as produced in the United States makes a good quality feeding material for hogs and its use for this purpose has in some cases been profitable. It is also attractive because it performs that admirable feat of taking what normally would be classed as waste products and transforming them into useful materials. However, if the proper sanitary precautions are observed, to prevent nuisance conditions and the spread of disease, the margin of profit becomes small or ceases to exist.

It might be well to determine to what extent the feeding of garbage to hogs is practiced in the United States. Sullivan, Maharg, and Hughes (7) state that there are approximately three-fourths of a million hogs on farms in California and that about 40 per cent of these hogs are now fed on garbage. In 1948 there were 417 garbage feeding establishments, an increase over the 355 reported in 1947. These authors state that it has been pretty well proven that one ton of garbage will produce approximately 50 lb. of pork.

In Maryland, Heyl (8) found that 17 out of 88 communities reporting their method of garbage disposal, during a recent survey, disposed of garbage by feeding to hogs. Helper (9) states that 66 of the 168 municipalities in Michigan reporting some form of garbage collection and disposal system are disposing of garbage by feeding to hogs.

Wright (10), in 1939, made a survey of cities of over 10,000 population with regard to methods of garbage disposal. A total of 403, or 52.7 per cent, of the 764 cities replying to the questionnaire disposed of municipally-collected garbage in whole or in part by feeding it to swine. Twenty-two of these cities maintained a municipal hog farm.

Snyder (11), in 1949, in a survey of refuse disposal in certain cities of over 10,000 population, found that only 19 of 153 cities reporting, or 7.5 per cent, use hog feeding as the method of garbage disposal. As this survey was somewhat limited and probably represents cities more advanced in their treatment of sanitation problems, the percentage using hog feeding as a method of disposal is too low to represent the average. There was undoubtedly some improvement between 1939 and 1949, however.

If hogs are permitted to feed on unsterilized garbage, the gates have immediately been opened to the infection

of pork used for human consumption and the risk of diseases attacking both humans and the animals. The fact that no serious loss of life or mass sickness has been attributed to this source of infection is undoubtedly the reason so little attention has been given to the problem.

Transmission of Trichinosis

Trichinosis, a disease caused by trichina, a small nematode parasistic in the rat, the pig, and man, is quite prevalent in the United States. The scientific name of the parasite is properly *Trichinella spiralis*. Two stages are distinguished—muscle trichina, the immature form, encysted and inactive; and intestinal trichina, the adult form, free and ultimately sexually mature. The species is highly specialized for parasitic existence. The encysted trichina in muscle tissue, if brought living into the stomach of some flesh eater, is set free by the digestion of the cyst. It passes into the intestine and within two and one half days reaches sexual maturity. After pairing, the male dies and the female grows greatly in size. The first young are produced in about one week from date of infection. Before giving birth to any, the female bores her way into an intestinal villus, pours out all the young into the lymph fluid and they are carried by the lymph glands into the muscles, which undergo granular degeneration, while a cyst is formed about each young trichina. Eighteen days are required to complete the process and the young trichina coiled within the cyst is ready for transfer to another host. Although very resistant against smoking, pickling, and even decomposition of meat, the trichina is readily killed by cooking, so that no danger attaches to the consumption of well-done pork. Prolonged cooking is necessary to bring the center of large pieces of meat to the proper temperature.

Raw garbage can be and, according to scientific evidence, often is in the United States the avenue of infection for human trichinosis. Scientific research by competent and acknowledged experts led them to conclude (10) that at the present time the evidence is overwhelmingly in support of the view that the hog fed on uncooked garbage is the chief source of human trichinosis. The importance of trichinosis as a public health problem cannot be ignored. Although it is seldom seen in epidemic proportions, a large number of the population is known to be infected. Some authorities report the incidence of the disease to range from 10 to 20 per cent of the total population of the United States.

Effect of Heat on Trichina

The use of garbage as hog feed is approved by most authorities if certain sanitary measures are observed. The primary measure is the sterilization of the garbage by boiling or some similar method. Zeller (12) states that there has been considerable discussion on the desirability of cooking garbage before feeding, but it is generally conceded that raw garbage is superior in feeding value to that which is cooked. Cooking causes injurious acids, alkalies, and other substances harmful to hogs (such as coffee grounds and acids from citrus fruit rinds) to spread throughout the garbage. Raw garbage enables the hog to use its power of food selection and refuse those foods that are unappetizing or harmful.

Ransom and Schwartz (13) reviewed the literature on the effects of heat on the infective larvae of *Trichinella spiralis* and conducted a series of experiments, in which it was found that the vitality of these larvae was quickly destroyed by exposure to a temperature of 55° C. (132° F.) gradually attained and that further exposure to temperatures in the neighborhood of 50° C. (122° F.) for a sufficient period of time rendered the larvae nonviable. More recently, Otto and Abrams (14)

have confirmed these results. The findings of Ransom and Schwartz formed the basis of federal inspection regulations governing the processing of certain pork products for the destruction of trichinae.

Wright and Bozicevich (15) concluded, as the result of certain experiments on the cooking of garbage before feeding to hogs to destroy trichinae in pork scraps, that the boiling of garbage for 30 min. in an open container will effect the destruction of trichina larvae in pieces of pork to 3 in. in thickness and probably in pieces of pork of greater thickness, provided the garbage is allowed to cool gradually. Such procedure would seem to constitute an effective measure for preventing the transmission of trichina infection in swine maintained on garbage and thus aid in the control of swine trichinosis primarily and human trichinosis secondarily.

The danger from trichinosis in garbage-fed hogs could be eliminated by keeping garbage containing bones and meat scraps separate from other garbage. However, this is not practical in most cases and would not offer protection against other diseases. The practice of cooking all garbage would seem to be the solution.

Canada requires the cooking of all garbage not produced on the premises where it is fed. The Canadians consider that cooked garbage produces good gains in hogs. The U. S. Chamber of Commerce Health Advisory Council (16) states that in Canada, where garbage is cooked before feeding it to hogs, trichinosis is one-twelfth as widespread as it is in the United States.

Other Diseases in Hogs

Other diseases affecting hogs are cholera, pneumonia, foot and mouth disease, swine plague, porcine tuberculosis, glanders, etc. Any, and probably all of these, can be transmitted to hogs through the media of sewage and/or garbage. All hogs on swine farms using garbage for food should be inoculated against hog cholera. In general, good sanitary conditions of the pens and feeding yards are the best protection against infection by the other diseases.

Dawes (17) states that "In the early days of the last World War, serious and very costly outbreaks of foot and mouth disease became so frequent in England that it was necessary to sterilize garbage at 212° F. for over 60 minutes to save the hog population." To date, over 4,000,000 tons of sterile and concentrated garbage have been sold to hog feeders and the demand continues. No case of foot and mouth disease has been reported from premises where only sterilized garbage is fed to hogs.

References

1. Smith, T., "Parasitism and Disease," p. 8. Princeton Univ. Press (1934).
2. Minett, F. C., Woolridge, G. H., and Sheather, A. L., "An Experimental Inquiry Concerning So-Called Sewage Poisoning in Cattle." *Vet. Record* (Feb. 10, 1934).
3. Crawford, A. B., and Frank, A. H., "Effect on Animal Health of Feeding Sewage." *Civil Eng.*, **10**, 8, 495 (1940).
4. Nelson, H., Wilson, H., and Robinson, M. C., "The Grazing of Cattle on Sewage Farms." *Jour. and Proc.*, Inst. Sew. Purif., Part 2, 189 (1947).
5. Christiansen, M. J., and Jepsen, A., *Water Poll. Research Jour.*, **19**, No. 7 (July, 1946).
6. Pramer, D., and Heukelekian, H., "The Survival of Tubercle Bacilli in Sewage Treatment Processes." THIS JOURNAL, **22**, 9, 1123 (Sept., 1950).
7. Sullivan, W., Maharg, E., and Hughes, E. H., "The Garbage Hog Feeding Business in California." Circ. 166, p. 4. California Agric. Ext. Serv., Univ. of California (Apr., 1950).
8. Heyl, E. G., "How Maryland Handles Municipal Refuse." *Amer. City*, **64**, 11, 95 (1949).
9. Helper, J. M., "Lectures Presented at The Inservice Training Courses of Garbage and Refuse Collection and Disposal," p. 4. School of Pub. Health, Univ. of Michigan (Oct. 27–28, 1947).
10. Wright, W. H., "Studies on Trichinosis.

XIV. A Survey of Municipal Garbage Disposal Methods as Related to the Spread of Trichinosis." *Pub. Health Rep.*, **55**, 1069 (June 14, 1940).
11. Snyder, C. W., "A Survey of Urban Rat Control in the U. S. A." *Modern Sanit.*, **1** (October and November, 1949).
12. Zeller, J. H., "Feeding Garbage to Hogs." A. H. D. No. 71, p. 4. Bur. of Animal Industry, U. S. Dept. Agric. (Feb., 1943).
13. Ransom, B. H., and Schwartz, B., "Effects of Heat on Trichinae." *Jour. Agric. Res.*, **17**, 201 (1919).
14. Otto, G. F., and Abrams, E., "Quantitative Studies on the Effect of Heat on Trichina (*Trichinella spiralis*) Larvae." *Amer. Jour. Hyg.*, **29**, Sect. D, 115 (1939).
15. Wright, W. H., and Bozicevich, J., "Experiments in the Cooking of Garbage for the Destruction of Trichinae in Pork Scraps." *Pub. Health Rep.*, **58**, 396 (Mar. 5, 1943).
16. U. S. Chamber of Commerce Health Advisory Council, "Trichinosis Incidence." *Amer. City*, **62**, 6, 13 (June, 1947).
17. Dawes, J. C., "U. S. Refuse Collection Practices." Reprint from *Amer. City* (Dec., 1950).

MICROBIOLOGICAL INSTITUTE RESEARCH GRANTS

Several grants among the total of 102 recently announced as being awarded to non-federal medical scientists by the Microbiological Institute of the National Institutes of Health, U.S.P.H.S., are for projects concerned with disease transmission or growth in sewage and other waterborne wastes. Among the grants listed are the following:

H. H. Anderson and H. G. Johnstone, Univ. of California Medical Center, San Francisco; $19,998; requirements for growth and control of *E. histolytica.*

S. G. Dunlop, Univ. of Colorado; $11,918; incidence and significance of intestinal pathogens in sewage-contaminated irrigation water and on food products irrigated therewith.

W. T. Calaway, Univ. of Florida; $5,775; biology and ecology of sewage filtration through sand.

J. G. Shaffer, Univ. of Louisville (Ky.); $10,000; growth requirements of *E. histolytica.*

W. L. Mallmann, Michigan State College, East Lansing; $4,200; development of test methods for enterococci and evaluation of their significance in polluted waters.

B. H. Ketchum, Woods Hole (Mass.) Oceanographic Institute; $14,634; dispersion of pollution in tidal waters.

M. P. Horwood, Mass. Institute of Technology; $13,014; further studies on effects of ultrasonic vibrations on bacteria.

T. A. Olson, Univ. of Minnesota; $12,000; study of toxic substances produced in water by blue-green algae.

W. Rudolfs, Rutgers Univ., New Brunswick, N. J.; $2,679; survival of tubercle bacilli in sewage treatment processes, streams, and water supplies.

R. Patrick, Academy of Natural Sciences of Philadelphia; $13,203; development of methods for ascertaining by a single test organism the median tolerance limit of important organisms in rejuvenescence of a stream for certain chemicals commonly found in industrial wastes.

F. K. Erickson and R. E. Hungate, State College of Washington; $6,172; microbiology and biochemistry of waste disposal processes.

STANDARDIZATION OF N/40 THIOSULFATE SOLUTIONS WITH SATURATED SOLUTIONS OF DISSOLVED OXYGEN

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The method proposed herein for the standardization of 0.025 N thiosulfate solutions is based on the reverse application of the Winkler (1) method, which is used for the determination of dissolved oxygen. Normally, the thiosulfate solutions used in the Winkler method are standardized against dichromate, bi-iodate, iodate, or periodate salts. In this method, oxygen-saturated distilled water at a known temperature and barometric pressure is used as the standardizing reagent for the thiosulfate solutions, eliminating the use of the aforementioned standardizing reagents.

The method is based on the procedure devised by Winkler (1) in 1888, for the determination of dissolved oxygen in water, the same method which is the basis for the dissolved oxygen determinations presently in use (5). In addition, it is necessary to obtain solution temperature readings accurate to 0.1° C. and barometric readings accurate to 1 mm., both of which are readily attainable. Finally, it is necessary to have available a table of accurately determined oxygen solubilities recorded at 0.1° C. intervals. Such a table originated with Fox (2), who prepared a table of oxygen solubilities, based on the Winkler method, expressed as the number of cubic centimeters of oxygen absorbed from a free, dry atmosphere by a known amount of distilled water at various temperatures. Whipple (3) later confirmed Fox's results, but corrected his values for the vapor pressure of water over the liquid phase, making available a table of dissolved oxygen values which was of considerably more practical value. This particular table is the one found in the 9th edition of "Standard Methods" (5). Elaborating on the table by Whipple and extending its use, Streeter (4) interpolated the values to intervals of 0.1° C. From this latter table (Table I) the saturation values for dissolved oxygen at 0.1° C. intervals up to 30° C. and at 760 mm. pressure are obtainable for use with the proposed method.

Preliminary Observations

A natural preliminary to this investigation was the necessity of determining the time required for the aeration of distilled water to assure that it became saturated with respect to dissolved oxygen. The aeration was accomplished using compressed air and an ordinary diffuser stone submerged in the distilled water. The results obtained are shown in Table II.

It will be noted from Table II that 15-min. aeration is sufficient to saturate freshly distilled water with oxygen. Differences in dissolved oxygen saturation values due to temperature fluctuations are also overcome within 15-min. periods. It is recommended that a 30-min. aeration period be used in order to permit oxygen-saturation and temperature equilibrium to be reached. This is especially important when the initial distilled water and room temperatures differ to any great extent. To avoid

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TABLE I.—Saturation Values of Dissolved Oxygen, in Parts per Million, for Temperatures from 0° to 30° C.[1]
(Under Normal Atmosphere at 760 mm. Pressure)

Temp. (°C.)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	14.62	14.58	14.54	14.50	14.46	14.42	14.39	14.35	14.31	14.27
1	14.23	14.19	14.15	14.11	14.07	14.03	14.00	13.96	13.92	13.88
2	13.84	13.80	13.77	13.73	13.70	13.66	13.62	13.59	13.55	13.52
3	13.48	13.44	13.41	13.38	13.34	13.30	13.27	13.24	13.20	13.16
4	13.13	13.10	13.06	13.03	13.00	12.97	12.93	12.90	12.87	12.83
5	12.80	12.77	12.74	12.70	12.67	12.64	12.61	12.58	12.54	12.51
6	12.48	12.45	12.42	12.39	12.36	12.32	12.29	12.26	12.23	12.20
7	12.17	12.14	12.11	12.08	12.05	12.02	11.99	11.96	11.93	11.90
8	11.87	11.84	11.81	11.79	11.76	11.73	11.70	11.67	11.65	11.62
9	11.59	11.56	11.54	11.51	11.49	11.46	11.43	11.41	11.38	11.36
10	11.33	11.31	11.28	11.25	11.23	11.21	11.18	11.15	11.13	11.11
11	11.08	11.06	11.03	11.00	10.98	10.96	10.93	10.90	10.88	10.86
12	10.83	10.81	10.78	10.76	10.74	10.71	10.69	10.67	10.65	10.62
13	10.60	10.58	10.55	10.53	10.51	10.48	10.46	10.44	10.42	10.39
14	10.37	10.35	10.33	10.30	10.28	10.26	10.24	10.22	10.19	10.17
15	10.15	10.13	10.11	10.09	10.07	10.05	10.03	10.01	9.99	9.97
16	9.95	9.93	9.91	9.89	9.87	9.85	9.82	9.80	9.78	9.76
17	9.74	9.72	9.70	9.68	9.66	9.64	9.62	9.60	9.58	9.56
18	9.54	9.52	9.50	9.48	9.46	9.44	9.43	9.41	9.39	9.37
19	9.35	9.33	9.31	9.30	9.28	9.26	9.24	9.22	9.21	9.19
20	9.17	9.15	9.13	9.12	9.10	9.08	9.06	9.04	9.03	9.01
21	8.99	8.98	8.96	8.94	8.93	8.91	8.89	8.88	8.86	8.85
22	8.83	8.81	8.80	8.78	8.77	8.75	8.74	8.72	8.71	8.69
23	8.68	8.66	8.65	8.63	8.62	8.60	8.59	8.57	8.56	8.54
24	8.53	8.51	8.50	8.48	8.47	8.45	8.44	8.42	8.41	8.39
25	8.38	8.36	8.35	8.33	8.32	8.30	8.28	8.27	8.25	8.24
26	8.22	8.20	8.19	8.17	8.16	8.14	8.13	8.11	8.10	8.08
27	8.07	8.05	8.04	8.02	8.01	7.99	7.98	7.96	7.95	7.93
28	7.92	7.90	7.89	7.87	7.86	7.84	7.83	7.81	7.80	7.78
29	7.77	7.75	7.74	7.73	7.71	7.70	7.69	7.67	7.66	7.64
30	7.63	—	—	—	—	—	—	—	—	—

[1] From table prepared by Streeter (4).

errors it is necessary that the aerated distilled water be treated with the standard reagents of the Winkler method immediately after the water temperature is taken.

Because many laboratories are set up to run routinely one of the Winkler method modifications for dissolved oxygen, it was decided to check one of the modifications against the basic Winkler method. Perhaps the most widely used modification of the Winkler method is the Alsterberg (4) (5) (sodium azide) modification. Therefore, it was chosen for the comparison. Using the same aerated distilled water and the same standardized thiosulfate solution, the results of the comparison are shown in Table III, which indicates no difference by either method.

Procedure and Results

In the following procedure all the reagents were prepared in accordance with the instructions contained in "Standard Methods" (5). A 1-l. portion of distilled water was aerated for

TABLE II.—Time Required for Oxygen Saturation of Distilled Water

Aeration Time (min.)	Temp. (°C.)	D. O. (p.p.m.)	
		Determined[1]	Sat. Value[2]
0	25.0	7.84	8.38
15	25.0	8.39	8.38
30	25.4	8.33	8.32
45	25.4	8.33	8.32
60	25.4	8.33	8.32
120	25.4	8.33	8.32

[1] Freshly distilled water. Values corrected to 760 mm.

[2] From table prepared by Streeter (Table I).

30 min. or longer, using an ordinary gas dispersion stone. At the end of the aeration period the temperature of the aerated distilled water was measured and recorded to the nearest 0.1° C. The barometric pressure was read at this time and recorded so that necessary corrections could be made. (Note:—If a barometer is not available in the laboratory the barometric pressure may be obtained from the local Weather Bureau office.) Immediately following the recording of the distilled water temperature, the aeration was stopped and the aerated distilled water, saturated with dissolved oxygen, was siphoned into at least three standard B.O.D. bottles. Each bottle was completely filled so that no air bubbles remained in the bottle when the stopper was replaced in the bottle. Immediately following filling, the procedure for the determination of dissolved oxygen was begun, using the Winkler method or the sodium azide modification, in accordance with the procedure described in "Standard Methods." When measuring out a sample to be titrated with the thiosulfate solution, it was necessary to correct the volume to be titrated for the loss of dissolved oxygen caused by the displacement of the original sample with reagents. The method for making this correction also is described in "Standard Methods."

TABLE III.—Comparison of the Winkler Method and the Sodium Azide Modification

Procedure	$Na_2S_2O_3$ Required[1] (ml.)
Winkler	9.04
Sodium Azide Mod.	9.04

[1] Average of three samples.

Comparative standardizations of the thiosulfate solution (approximately 0.025 N) were made using analytical reagent grades of potassium dichromate ($K_2Cr_2O_7$), potassium iodate (KIO_3), and potassium periodate (KIO_4) as the standardizing reagent. Procedures for the standardization of thiosulfate solutions using these reagents may be found in various analytical text and reference books (5) (7) (8) (9) (10).

The only piece of laboratory equipment used in this work which might not be considered normal laboratory equipment was a burette for the titration which was calibrated at 0.05-ml. intervals, permitting estimations to the nearest 0.01 ml.

TABLE IV.—Comparative Summary of Thiosulfate Standardizations

Line	Standardized With	Normality of $Na_2S_2O_3$ Solution[1]	Average Normality	Deviation from Av. Normality	Dev. from Av. Norm. (%)
1	$K_2Cr_2O_7$	0.0251	0.0254	0.0003	1.2
2	KIO_3	0.0252		0.0002	0.8
3	KIO_4	0.0258		0.0004	1.6
4	D.O., 9.6° C.	0.0255	—	0.0001	0.4
5	D.O., 21.1° C.	0.0255	—	0.0001	0.4
6	D.O., 28.4° C.	0.0257	—	0.0003	1.2

[1] Average of 3 determinations.

The comparative results of the standardization of approximately 0.025 N thiosulfate solution using the accepted standardization procedures and the suggested dissolved oxygen procedure are given in Table IV. The dissolved oxygen method determinations were made at temperatures of 9.6°, 20.1°, and 28.4° C. to ascertain its reliability at various temperatures below 30°C. The normality value shown for each method of standardization is an average of triplicate determinations. It will be noted from Table IV that the normality of the thiosulfate solution varied, depending on the type of standardizing reagent used (Lines 1, 2, and 3). An average of these three values was taken as a basis for comparison with the results obtained using the saturated dissolved oxygen method. The per cent deviation values for the D.O. method from the established average are generally less than the corresponding deviations for the other methods of standardizing thiosulfate solutions.

Outline of Procedure

1. Aerate 1.5 l. of distilled water vigorously for at least 30 min. to assure saturation with dissolved oxygen.

2. Observe and record the temperature of the aerated distilled water and the barometric pressure at the end of the aeration period.

3. Immediately fill three standard B.O.D. bottles with the aerated water by siphoning. Replace bottle stopper, being certain that no air bubbles are entrained.

4. Proceed immediately with the standard D.O. determination using either the Winkler method or the sodium azide modification of the Winkler method, in the same manner used when making D.O. determinations, observing the same precautions and technic. The volume of iodine solution used for the final titration must be corrected for the displacement of dissolved oxygen by the reagents used.

Calculations

The normality of the thiosulfate solution may be calculated as follows, using the following symbols:

O_s = dissolved oxygen saturation (p.p.m.) at the observed temperature (°C.) and 760 mm. pressure (from Table I).
O_c = dissolved oxygen saturation (p.p.m.) at the observed temperature (°C.) corrected for the observed barometric pressure (mm.)
P_s = 760 mm.
P_o = observed barometric pressure (mm.)
N = normality of thiosulfate solution.
V = volume of original sample titrated (ml.)
v = volume of thiosulfate solution used for titration (ml.)

Dissolved oxygen correction for observed barometric pressure:

$$O_c = \frac{O_s P_o}{P_s} = \frac{O_s P_o}{760} \qquad (1)$$

Normality of thiosulfate solution:

$$N = 0.025 \left(\frac{O_c}{v}\right)\left(\frac{V}{200}\right) \qquad (2)$$

Combining Eqs. 1 and 2:

$$N = 0.025 \left(\frac{O_s}{v}\right)\left(\frac{P_o}{760}\right)\left(\frac{V}{200}\right) \qquad (3)$$

As an example, the following data were obtained while standardizing a thiosulfate solution of approximately 0.025 N: Temperature of oxygen saturated distilled water = 20.5° C.; dissolved oxygen saturation at 20.5° C. and 760 mm. barometric pressure, from Streeter's table, O_s = 9.09 p.p.m.; barometric pressure at saturation time, P_o = 764 mm.; and volume of thiosulfate solution required to titrate 200 ml. of original sample, v = 9.00 ml.

Substituting in Eq. 3:

$$N = 0.025\left(\frac{9.09}{9.00}\right)\left(\frac{764}{760}\right)\left(\frac{200}{200}\right) = 0.0254$$

Summary and Conclusions

A proposed method for the standardization of N/40 thiosulfate solutions is presented for specific application in the fields of industrial waste and sewage analysis. The method is based on the use of oxygen-saturated distilled water as a standardizing medium for approximately N/40 thiosulfate solutions, which are used as a reagent in the dissolved oxygen determination using the Winkler method or the sodium azide modification of the Winkler method. Simply stated, it is a procedure whereby the Winkler method is used to standardize N/40 thiosulfate solutions by means of oxygen-saturated distilled water solutions of known dissolved oxygen content. These values are readily obtainable from prepared tables of oxygen saturation values under standard conditions and easily corrected to the conditions existing at the time of the determination. The standardization procedure requires very little more care than is exercised ordinarily in the routine determinations of dissolved oxygen. The equipment used is that normally found in an average laboratory, with the possible exception of a burette calibrated to 0.05 ml. Atmospheric pressure values may be obtained from local Weather Bureau offices if a barometer is not available. The determination is limited to temperatures up to 30° C., the limitation being due to the lack of suitable dissolved oxygen values above that temperature.

The proposed method of thiosulfate solution standardization is limited to concentrations of N/10 or less, due to the limitation placed on the method by the relatively small solubility of oxygen in water. Attempting to standardize thiosulfate solutions of greater concentration than N/10 would lead to inaccurate results unless the sample titrated was increased to such a large quantity that the determination would be made unwieldy.

The advantages gained by this proposed method of N/40 thiosulfate solution standardization lie in its speed and simplicity. Drying, weighing, and handling of standardizing reagent are eliminated. The proposed method may be used to particular advantage in small sewage and industrial waste control laboratories, as it eliminates the need for an analytical balance or the necessity of purchasing the relatively expensive standardized thiosulfate solutions. It also eliminates the dependence upon some larger laboratory as a source of standardized thiosulfate solutions.

References

1. Winkler, L. W., "The Determination of Dissolved Oxygen in Water." *Ber.*, **21**, 2843 (1888).
2. Fox, C. J. J., "On the Coefficients of Absorption of Nitrogen and Oxygen in Distilled Water and Atmospheric Carbonic Acid in Sea Water." *Trans. Faraday Soc.*, **5**, 68 (1909).
3. Whipple, G. C., and Whipple, M. C., "Solubility of Oxygen in Sea Water." *Jour., Am. Chem. Soc.*, **33**, 362 (1911).
4. Streeter, H. W., "Measures of Natural Oxidation in Polluted Streams. II. The Reaeration Factor and Oxygen Balance." *Sewage Works Jour.*, **7**, 3, 534 (May, 1935).
5. "Standard Methods for the Examination of Water and Sewage." 9th Ed. Am. Pub. Health Assn., New York (1946).
6. Alsterberg, G., "Methods for the Determination of Elementary Oxygen Dissolved in Water in the Presence of Nitrite." *Biochem. Z.*, **159**, 36 (1925).
7. Snell, F. D., and Biffen, F. M., "Commercial Methods of Analysis." 1st Ed. McGraw-Hill, New York (1944).
8. Hillebrand, W. F., and Lundell, G. E. F., "Applied Inorganic Analysis." 10th Printing. Wiley, New York (1948).
9. Treadwell, F. P., and Hall, W. T., "Analytical Chemistry." 9th Ed. Wiley, New York (1948).
10. Scott, W. W., "Standard Methods of Chemical Analysis." Vol. II, 5th Ed. Van Nostrand, New York (1939).

THE BIOSORPTION PROCESS OF SEWAGE AND WASTE TREATMENT *

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Since the discovery and acceptance of the various modern methods of sewage and other waste treatment there has been an almost continuous search for ways to improve each process, both as regards the degree of purification achieved and the simplification of plant and process operation. In more recent years the ever increasing demand for more and better domestic sewage and industrial waste treatment has led to intensified efforts to improve accepted processes and to develop new ones. Many of these efforts have had as their chief aim the reduction of treatment costs, both as regards cost of operation and initial plant cost. This has led to the development of accelerated processes or high-rate treatments. Other efforts have aimed chiefly at finding and developing ways and means of plant operation which would assure a high degree of purification at all times, even in the face of the complex and variable nature of the wastes involved. Those who are responsible for the treatment of wastes, especially domestic sewage, with or without industrial waste, will welcome a not too costly process which will give a continuously high degree of purification with a minimum of plant control and adjustment.

Reason for Studies

Austin, Tex., like other Southwestern cities, has had a rapid increase in population since World War II and with it has come a corresponding increase in sewage volume and load. Although Austin does not have large industries, it does have a large city-owned abattoir, from which the sewage treatment plant receives large quantities of blood, paunch contents, and other normal packinghouse wastes. In addition, there are several large poultry processing plants, from which an undetermined amount of waste is received. The rapid growth of the city, the increasing popularity of garbage grinders, the expanding poultry processing industry, and perhaps other factors, have contributed to ever increasing loads received by the sewage treatment plant.

In 1947 it was realized that the existing conventional activated sludge plant, which was designed for a 6-m.g.d. flow, could not meet the ever increasing loads. Therefore, in late 1947 serious studies were begun aimed at developing new operational procedures that would permit the existing plant to treat larger flows and greater loads and still maintain a high degree of purification with a minimum of plant upsets. At that time it was also hoped that the results of some of the studies would lead to more efficient and economical design of future plant expansions and some of the efforts were directed toward this end.

It is believed that the laboratory, pilot plant, and plant studies made thus far have definitely proven worthwhile. By making certain operational changes, primary treatment is now given to all of the sewage flow,

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which in 1950 averaged 10.663 m.g.d., and secondary treatment is given to an average of a little more than 8 m.g.d. (the 1950 average was 8.439 m.g.d.)—this in a plant designed for a flow of 6.0 m.g.d. back in 1935. What is felt to be of even greater importance, however, is the fact that the studies have led to the development of a new and improved process of sewage and waste treatment, which has been named the "Biosorption" process.

Process Steps

Essentially the Biosorption process is an accelerated or high-rate treatment process. Briefly, it consists of the following distinct treatment steps:

1. Activated sludge is brought into intimate contact with raw sewage. Brief mixing of the two is accomplished either mechanically or with air. The activated sludge adsorbs and absorbs a very high percentage of both the suspended solids and dissolved pollutional material.

2. After the brief mixing, the mixed liquor flows to a clarifier, where it is settled. The effluent is clear, low in B.O.D., and low in suspended solids. This is the plant effluent, ready for final disposal.

3. The sludge from the clarifier, which now contains the original activated sludge plus the adsorbed and absorbed suspended and dissolved pollutional matter from the raw sewage, is conducted to an aeration compartment, where it is aerobically digested in preparation for recycling. In other words, the sludge from the clarifier is reactivated by means of aeration so it can again be used in the mixing compartment for removing polluting materials, thus making the process continuous.

Pilot Plant Tests

Early in 1950 a 15- to 20-g.p.m. pilot plant (Figure 1) was designed and built to thoroughly test out ideas and theories conceived as a result of the previous laboratory studies. The essential units of the plant are a mixing tank, a clarifier, an aeration tank (aero-digester), and such necessary auxiliary equipment as air supply and air diffusers, sludge pump, and the necessary piping. Figure 2 gives a flow diagram of the pilot plant. On the basis of 15-g.p.m. raw sewage flow and 15-g.p.m. return sludge rate, the pilot plant units provided detention periods as follows: Mixing tank, 15 min.; clarifier, 65 min. (approximately 900 g.p.d. per sq. ft. rise rate); and sludge aeration tank, 90 min. It should be noted that the detention periods for the mixing tank and the sludge aeration tank increase with a decrease in the percentage of sludge return, and that excess sludge may be wasted at either location No. 1 or No. 2.

The pilot plant has been operated exclusively on raw sewage and data have been collected on a wide range of flows of both raw sewage and return sludge. In this process the term "return sludge" refers to the sludge conducted from the bottom of the clarifier to the areo-digester (aeration tank) and thence back to the mixing tank. The plant has been operated on both constant flows—that is, flows of 10, 15, or 20 g.p.m. over 24-hr. periods—and on variable flows corresponding to the variations of flows normally received over a 24-hr. period in the existing large conventional activated sludge plant. The plant also has been operated on constant return sludge rates and on return sludge rates varied with varying raw sewage flows and loads. Except when small plant operational difficulties were encountered, such as partially clogged sludge lines, the plant has given excellent results as regards B.O.D. and suspended solids removal over a wide range of raw sewage flows and return sludge rates.

The pilot plant data collected thus far show that:

1. When a good activated sludge, in proper amount, and raw sewage are mixed with air for a period ranging from 15 to 30 min. and the resulting mixed liquor is then permitted to settle, it is possible to obtain B.O.D. and suspended solids reduction in the 90 to 95 per cent range; extremes in the pilot plant operation have ranged from 85 to 99 per cent reductions. Low reductions have invariably been traceable to small plant operational difficulties, such as clogged sludge lines. By proper amount of activated sludge is meant sufficient "return sludge" to adsorb and absorb the suspended and dissolved pollutional matter in the raw sewage. The volume percentage required has been found to be in the same range as that required in good conventional activated sludge plant operation. However, it also has been found that excellent results can be obtained by maintaining the return sludge rate at the maximum required for peak flows and loads, thus reducing the operational control necessary.

2. After the brief air mix, the sludge in the resulting mixed liquor, which now contains both the original activated sludge plus the suspended and dissolved pollutional matter, has as good or better settling characteristics as the activated sludge in the mixed liquor of a satisfactorily operating conventional activated sludge plant. On the basis of raw sewage flow rates, the settling time and, therefore, the clarifier capacity required is no greater and will probably be less than that required in conventional activated sludge plants.

3. The settled and concentrated sludge from the clarifier can be aerated in its heavy concentration and com-

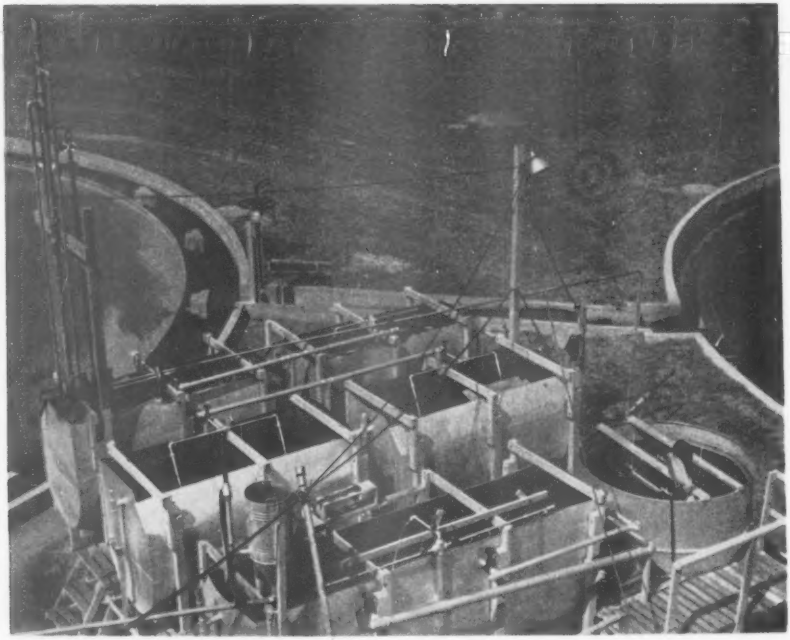

FIGURE 1.—Biosorption pilot plant at Austin, Tex.

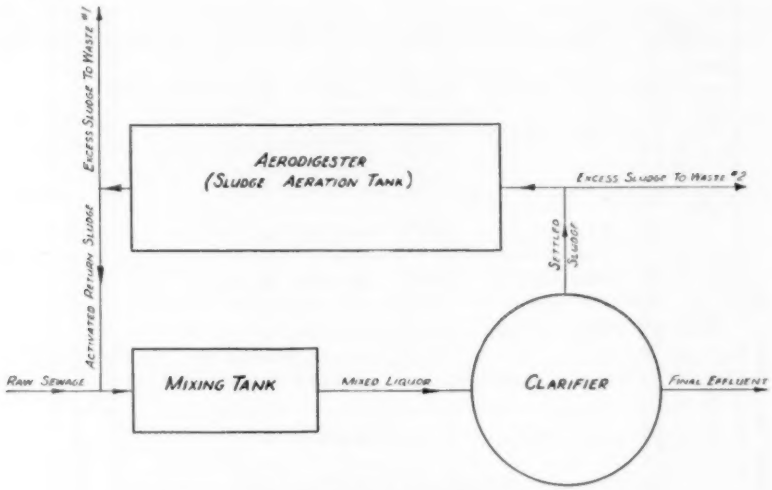

FIGURE 2.—Flow diagram of Biosorption pilot plant.

pletely restored or reactivated to its original adsorptive and absorptive powers so that it can be recycled to make the process continuous. Calculated on the basis of raw sewage flow rates, the aeration time required for reactivation of the concentrated sludge is in the range of 90 min.

4. The amount of excess sludge is about the same as from the conventional activated sludge process. However, there is available a choice in the point of drawoff; it is possible to waste either from the settled but unaerated sludge or from the more stable aerated sludge. The choice of the point of drawoff will depend on the method to be used for the disposal of the excess sludge.

The Biosorption process pilot plant has given excellent, trouble-free operation over long periods with a minimum of plant adjustment. By setting the return sludge rate for the maximum requirement, the plant has operated successfully without upset until there was a mechanical stoppage or breakdown, such as may be expected in the operation of very small plants. To reduce the number of sludge line stoppages the plant has been operated over long periods on a 1 to 1 volume ratio of return activated sludge to raw sewage. Table I gives pilot plant data obtained during January, 1951, when the plant was operated on a high return sludge rate.

Experience with the pilot plant thus far shows the Biosorption process to be much less subject to upsets than is the case with the conventional activated sludge process. The process shows a remarkable ability to adjust itself to both high and low flows and loads, and will absorb shock loads without difficulty if the return sludge rate is sufficient to absorb the pollutional matter. Over-aeration of the sludge during low flows and low loads does not seem to affect the operation, probably because if there is any denitrification it will occur during the mixing of the raw sewage and sludge and not in the clarifier, as is the case in the conventional activated sludge process. In this connection, it is of interest to note that bulking or rising

TABLE I.—Pilot Plant Data[1,2] on Biosorption Process, Austin, Tex., January, 1951

Date	Flows (g.p.m.)		Suspended Solids (p.p.m.)					Mixed Liquor % Vol.	Sludge Index	B.O.D. (p.p.m.)			pH		Turbidity		NH_3—N (p.p.m.)		NO_3—N (p.p.m.)		NO_2—N (p.p.m.)		D.O. Final Effl. (p.p.m.)
	Raw Sewage[3]	Return Sludge	Raw Sewage[3]	Final Effl.	% Red.	Return Sludge	Mixed Liquor			Raw Sewage	Final Effl.	% Red.	Raw Sewage	Final Effl.	Raw Sewage	Final Effl.	Raw Sewage	Final Effl.	Aero-Dig.	Final Effl.	Aero-Dig.	Final Effl.	
1 M	5-15-10	15	—	—	—	—	—	60.6	—	—	—	—	7.1	7.3	—	—	—	—	—	—	—	—	—
2 T	5-15-10	15	229	9.0	96.1	5,450	3,440	89.2	259	320	20.4	93.6	7.1	7.3	88	5	26	26	0.0	0.0	0.0	0.0	0.0
3 W	5-15-10	15	231	5.6	97.6	6,080	3,800	87.6	231	260	16.8	93.5	7.1	7.2	90	5	26	22	tr.	tr.	0.0	0.0	0.0
4 T	5-15-10	15	241	34.0	85.9	5,970	3,450	85.2	247	240	19.2	92.0	7.3	7.2	90	6	28	22	tr.	tr.	0.0	0.0	0.0
5 F	5-15-10	15	—	—	—	—	—	85.8	—	—	—	—	7.1	7.2	—	—	—	—	—	—	—	—	—
6 S	5-15-10	15	—	—	—	—	—	90.6	—	—	—	—	7.2	7.1	—	—	—	—	—	—	—	—	—
7 S	5-15-10	15	190	5.5	97.1	4,930	3,200	85.4	267	220	9.6	95.6	7.2	7.1	88	5	26	26	tr.	tr.	0.0	0.0	—
8 M	5-15-10	15	274	20.8	92.4	5,020	3,040	71.2	234	—	—	—	7.2	7.3	90	6	26	16	tr.	tr.	0.0	0.0	0.6
9 T	5-15-10	15	215	15.6	92.7	5,280	3,030	87.0	287	320	38.4	88.0	7.2	7.3	92	7	26	22	tr.	tr.	0.0	0.0	0.0
10 W	5-15-10	15	228	11.6	94.9	5,040	3,040	81.6	268	240	33.6	86.0	7.2	7.3	95	4	26	22	tr.	tr.	0.0	0.0	0.0
11 T	5-15-10	15	—	—	—	—	—	91.4	—	—	—	—	7.1	7.2	—	—	24	22	tr.	tr.	0.0	0.0	0.0
12 F	5-15-10	15	—	—	—	—	—	94.4	—	—	—	—	7.1	7.3	—	—	—	—	—	—	—	—	—
13 S	5-15-10	15	—	—	—	—	—	93.0	—	—	—	—	7.1	7.3	—	—	—	—	—	—	—	—	—
14 S	5-15-10	15	219	9.6	95.6	5,440	4,030	88.4	219	200	16.8	91.6	7.2	7.3	68	3	26	26	0.4	0.4	0.0	0.0	—
15 M	5-15-10	15	—	—	—	—	—	83.6	—	—	—	—	7.3	7.3	—	—	26	26	tr.	tr.	0.0	0.0	0.0
16 T	5-15-10	15	244	14.8	93.9	5,530	3,100	76.0	245	240	28.8	88.0	7.4	7.4	88	8	26	22	tr.	tr.	0.0	0.0	0.0
17 W	5-15-10	15	259	18.8	92.7	4,450	2,990	73.4	245	—	—	—	7.0	7.3	92	6	28	22	tr.	tr.	0.0	0.0	0.0
18 T	5-15-10	15	—	—	—	—	—	69.8	—	—	—	—	7.2	7.3	—	—	—	—	—	—	—	—	—
19 F	5-15-10	15	—	—	—	—	—	73.2	—	—	—	—	7.3	7.4	—	—	—	—	—	—	—	—	—
20 S	5-15-10	15	—	—	—	—	—	69.6	—	—	—	—	7.3	7.4	—	—	—	—	—	—	—	—	—
21 S	5-15-10	15	194	19.6	89.9	4,860	2,900	69.2	239	—	—	—	7.2	7.3	80	4	26	24	tr.	tr.	0.0	0.0	—
22 M	5-15-10	15	212	10.4	95.1	4,630	2,860	76.0	266	—	—	—	7.2	7.3	88	5	26	24	tr.	tr.	0.0	0.0	tr.
23 T	5-15-10	15	221	9.2	95.8	4,730	2,710	81.4	300	260	12.0	95.4	7.2	7.4	90	5	27	22	0.3	0.3	0.0	0.0	0.0
24 W	5-15-10	15	228	11.2	95.1	5,730	3,810	81.6	247	300	10.8	96.4	7.1	7.4	95	5	26	22	0.5	0.5	0.0	0.0	0.0
25 T	5-15-10	15	269	24.0	91.1	5,380	3,640	81.8	225	300	12.0	96.0	7.1	7.2	90	6	26	19	0.5	0.5	0.0	0.0	0.0
26 F	5-15-10	15	—	—	—	—	—	72.8	—	—	—	—	7.1	7.3	—	—	—	—	—	—	—	—	0.2
27 S	5-15-10	15	—	—	—	—	—	64.8	—	—	—	—	7.2	7.3	—	—	—	—	—	—	—	—	—
28 S	5-15-10	15	166	11.2	93.3	4,970	2,980	66.6	224	—	—	—	7.1	7.3	68	3	26	23	tr.	tr.	0.0	0.0	—
29 M	5-15-10	15	—	—	—	—	—	67.6	—	—	—	—	7.2	7.3	—	—	—	—	—	—	—	—	—
30 T	5-15-10	15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
31 W	5-15-10	15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Max.	—	—	274	34.0	97.6	6,080	4,030	—	—	320	38.4	96.4	—	—	—	—	—	—	—	—	—	—	—
Min.	—	—	166	5.5	85.9	4,450	2,710	—	—	200	9.6	85.0	—	—	—	—	—	—	—	—	—	—	—
Av.	—	—	226	13.9	93.8	5,218	3,251	—	—	264	19.9	92.5	—	—	—	—	—	—	—	—	—	—	—

[1] All the tests except D.O. made on composite samples.

[2] Retention periods for 15 g.p.m. raw sewage and 15 g.p.m. return sludge rate were as follows: Mixing chamber 14.3 min.; Clarifier 65 min., 910 Gal./sq. ft./day rise rate. Aerodigester 96.0 min.

[3] During the January, 1951, test run the raw sewage flow rates were changed to correspond with the flow rates in the large plant. This schedule was as follows: 5 g.p.m. from 2:00 A.M. to 10:00 A.M., 15 g.p.m. from 10:00 A.M. to 6:00 P.M., and 10 g.p.m. from 6:00 P.M. to 2:00 A.M. Return sludge rates were maintained at 15 g.p.m.

[4] "Aero-digester" refers to aeration chamber for concentrated sludge.

sludge has not been experienced in the pilot plant clarifier.

Conclusions

It is believed that the Biosorption process has the following advantages over the conventional activated sludge process:

1. It requires less aeration tank capacity. Because the so-called mixed liquor, consisting of sewage and return sludge, is given only a brief mix, only a small mixing compartment is needed. Since the real aeration or reactivation is accomplished in the settled and concentrated sludge and not in the mixed liquor, a much smaller aeration tank capacity is required.

2. It is much easier to maintain a consistently high degree of purification. A minimum of plant and process adjustments are required for a wide range in raw sewage flows and loads.

3. The process operates well on raw sewage. This eliminates the need for primary clarification and the costly disposal of raw sludge. It also eliminates the odors which are common to the operation of primary clarifiers.

PROGRESS REPORTED BY OHIO VALLEY COMMISSION

Fair progress in catching up on municipal sewage treatment requirements was reported at the third annual meeting of the Ohio River Valley Water Sanitation Commission, held in Cincinnati, Ohio, on July 11, 1951. Information from the eight states signatory to the commission compact shows that 39 per cent of the wastes from 8,500,000 people in the valley is receiving some form of treatment and that new plants under construction will serve another 8 per cent.

Whether or not the rate of new construction can be maintained depends in some measure on the ability to get materials and to float bond issues, according to a Commission spokesman. Final plans have been completed and approved for plants serving 20 per cent of the population in the valley and another 17 per cent has final plans in preparation. It was pointed out, however, that the uncertainties created by the national defense program could have a retarding effect. The hope was expressed that pollution control projects would be recognized as an essential element in promoting national welfare in terms of water conservation and thus be granted priority.

Among other actions taken by the Commission was authorization to form a Water Users Action Committee that would be made up of municipal and industrial representatives from water plants on the Ohio River. The purpose of this group—who have a vital interest as users of Ohio River water—would be to monitor the river's quality at regular intervals. Tests made by the committee members and correlated by the Commission staff would not only give a yardstick for gaging water quality improvement, but also would provide a means for tracing the course of contaminants in the river.

Industrial Wastes

DISPOSAL OF CITRUS BY-PRODUCTS WASTES AT ONTARIO, CALIF.

By Harvey F. Ludwig, Gordon W. Ludwig, and J. A. Finley

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Introduction

The Exchange Orange Products Company of Ontario, Calif., is one of the largest citrus fruit processing plants in the United States. The raw products received by the plant are oranges, lemons, and grapefruit, from which are produced canned citrus juices, juice concentrates, citrus oils, dried meal, molasses, and other products. During recent years the quantities of fruit processed have approximated 15,000 tons per month, ranging from an average minimum of 3,000 tons per month during December to an average maximum of 27,000 tons during August (see Table I). The typical operations year at the plant is made up of distinct processing periods, which correspond to the types of citrus fruits available. From December through May these are principally navel oranges; from June through November, valencia oranges; and during the remaining months, between orange seasons, lemons and grapefruit.

The processes which take place within the plant are those typical of the citrus by-products industry. First the fruit is juiced and then citrus oil is removed from the peel. Juices are canned directly or concentrated (either as base concentrate or as frozen concentrate). A portion of the peel passes to the pectin plant, where pectin is removed. The remaining peel is limed and pressed. Pulp from the presses, and also from the pectin plant, is dried in rotary dryers and sold as dried meal. A portion of the peel press liquor is further processed to produce citrus molasses.

Waste Characteristics

Figure 1 shows the volumes and types of non-sanitary liquid wastes produced by the Ontario plant. The total daily flow, which is estimated to average 0.70 m.g.d., is made up of five principal fractions: Cooling water, pectin wastes, pulp press liquor, processing plant wastes, and cannery floor washings.

A program of sampling and analysis was conducted in 1948 to determine the pertinent characteristics of each of these fractions and of their composite flow. During the testing period the plant was processing oranges uniformly throughout the 24 hours of the day, at the normal 700 tons per day rate. Composite samples of each fraction and of the total industrial sewage flow were collected over an 8-hr. shift, and each sample was analyzed to determine its concentration of suspended solids, B.O.D. (5-day, 20° C.), and settleable solids. Principal mineral characteristics were also determined for the sample of the total flow.

TABLE I.—Average Monthly Tonnages of Citrus Fruits Processed by Exchange Orange Products Company

Month	Tons
January	9,500
February	10,800
March	10,900
April	12,800
May	18,600
June	18,000
July	21,900
August	26,900
September	19,500
October	18,400
November	8,000
December	3,000
Average	14,850

Mineral Analyses

The major ion constituents of the sample of total flow were as shown in Table II. From these data the sodium ratio of the waste is computed to be 37 per cent. Also determined were the following: Acidity, 300 p.p.m.; pH, 5.0; and boron, 0.1 p.p.m. as B.

Other boron determinations, made from time to time on grab samples of the total flow, showed this constituent to range from 0.1 to approximately 1.0 p.p.m. depending upon whether the raw citrus fruit received at the plant had previously undergone a packing-plant washing operation.

TABLE II.—Major Ion Constituents in Total Flow Sample

Metal Ion	(p.p.m.)	(mE./l.)[1]	Non-Metal Ion	(p.p.m.)	(mE./l.)[1]
Ca	71	3.54	HCO_3	244	4.00
Mg	18	1.45	Cl	117	3.30
Na (K)[2]	53	2.96	SO_4	31	0.65
Total	—	7.95	—	—	7.95

[1] Milliequivalents per liter.
[2] By difference.

Organic Analysis

Organic analyses data are presented in Table III, which gives the measured concentration of each constituent, and also the computed total daily production of each constituent corresponding to the average plant processing capacity of 700 tons per day.

The total dry weight of suspended solids leaving the plant each day

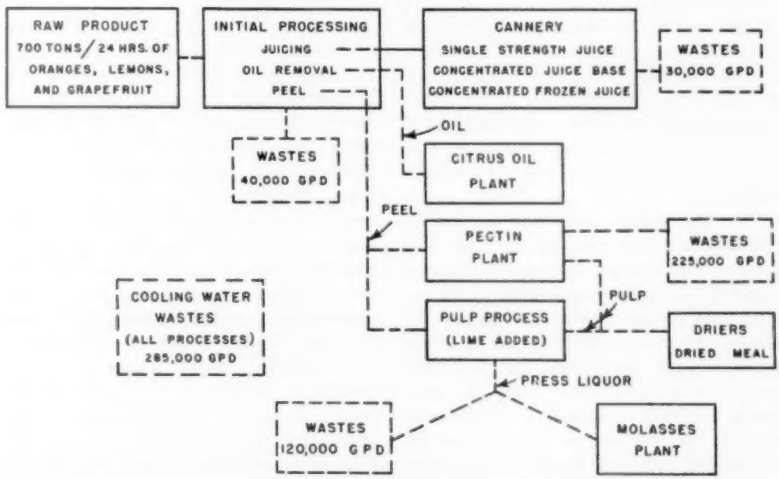

FIGURE 1.—Types and daily amounts of wastes produced by citrus plant processing operations.

TABLE III.—Organic Loadings Discharged to Industrial Sewer at 700-Ton per Day Processing Rate

Waste Component	Volume (1,000 g.p.d.)	Suspended Solids		B.O.D. (5-day)		Settleable Solids	
		(p.p.m.)	(lb./day)	(p.p.m.)	(lb./day)	(ml./l.)	(1,000 g.p.d.)
Cooling water	285	765	1,820	100	240	27	7.7
Pectin wastes	225	1,790	3,350	2,720	5,100	148	33.3
Pulp press liquor	120	780	390	9,850	4,920	290	17.4
Processing wastes	40	3,400	1,130	3,230	1,070	157	6.3
Cannery floor washings	30	685	170	970	240	74	2.2
Composite wastes	700	1,200	7,000	2,100	12,200	100	70.0

closely approximates 7,000 lb. Of this total, approximately 80 per cent is volatile or organic and 20 per cent is mineral or non-organic. Almost one-half the total suspended solids is derived from the pectin wastes.

The settleable solids total 70,000 g.p.d. Approximately one-half of this is derived from the pectin wastes, and about one-quarter from the pulp press liquor.

The B.O.D. contained in the daily discharge is approximately 12,000 lb., or 6 tons. Most of this is derived from the pulp press liquor and from the pectin wastes. Of the total B.O.D. concentration of 2,100 p.p.m. in the composite waste tested, approximately 80 per cent was found to be soluble B.O.D.; that is, the B.O.D. of the filtrate of the composite waste was 1,650 p.p.m. The B.O.D. of the clear supernatant from the composite waste after 2-hr. laboratory settling was 1,850 p.p.m., about 90 per cent of the total.

The foregoing data correspond to conditions when about half of the pulp press liquor produced in the plant is being converted to molasses, with the other half discharged to waste. However, the fraction of pulp press liquor converted to molasses varies with the market price for molasses. When no liquor is being converted, the total daily productions of suspended solids, settleable solids, and B.O.D. are increased by amounts of 5, 26, and 43 per cent, respectively.

It is noted that the organic content of the plant wastes, when expressed in amounts per ton of fruit processed, is of the same magnitude as that of similar wastes produced at other Southern California citrus by-products plants (1).

Plan of Waste Treatment

For many years, from 1928 to 1949, the entire industrial sewage flow from the plant was disposed of by ponding followed by spreading of the pond effluent on sandy ground. Both ponding and spreading were performed within a small 20-acre site located on Francis Avenue, resulting in very heavy applications of waste per unit area of land. Nevertheless, the mass of liquid was disposed of, principally by downward percolation, with the suspended solids being strained out and retained at the ground surface. This scheme of disposal was not satisfactory from several points of view: not only did the solids settle at the bottom and edges of the ponds and ferment to produce obnoxious odors, especially during the summer, but also the continued heavy loadings of waste maintained wet pockets and wet patches of mat scattered throughout the spreading area, resulting in undesirable breeding of nuisance insects. However, this experience demonstrated the feasibility of percolation as an efficient means for disposal of large volumes of the wastes, provided that the operation be conducted

in a manner designed to eliminate the nuisances described. The soils of this area (described in a subsequent section), and in fact of practically the entire Chino Basin in which Ontario is located, are principally sands with high drainage rates. These sands are ideal natural filters, capable of percolating away very large amounts of soluble organic matter. Also, check analyses of the soil and of the underground waters (discussed hereinafter) in the vicinity of the Francis Avenue site showed no apparent detrimental effect or deterioration to either. It was concluded that continued disposal by percolation would be by far the most economical means for disposing of the roughly 9,600 lb. or more of soluble B.O.D. produced each day, but that a larger area of land would be required to permit sufficient dispersion of the wastes to eliminate nuisances. Accordingly, a new site of 240 acres was acquired in 1948, located on Edison Avenue, as shown in Figure 2.

The 240-acre site was divided into four tracts of approximately 54 acres (exclusive of farm buildings, etc.), and each of the tracts was further subdivided into six plots of 9 acres each. All of the wastes for one day (24 hr.) are discharged to a single 9-acre plot, resulting in a 2.6-in depth of applica-

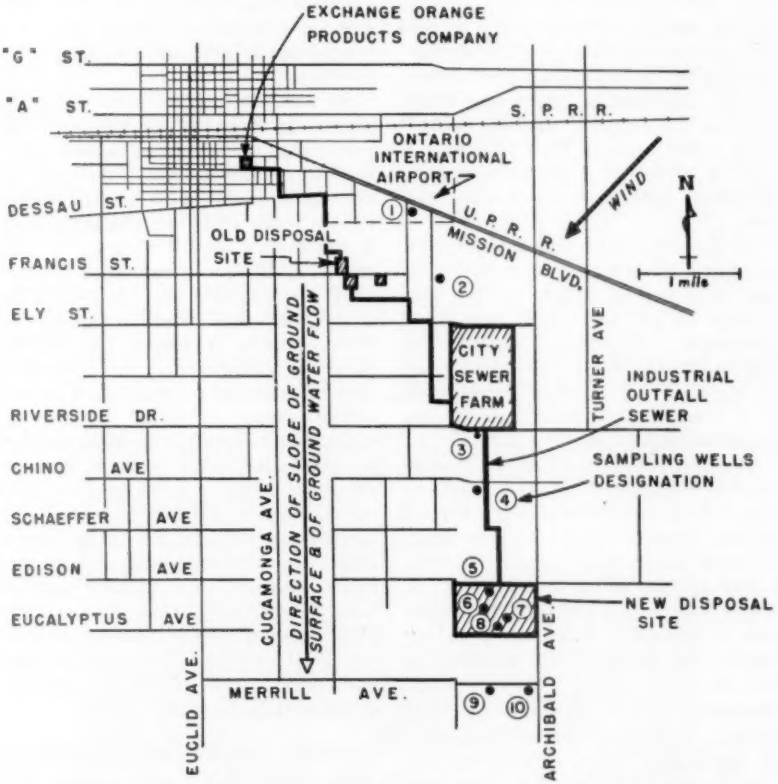

FIGURE 2.—Vicinity map, showing location of spreading areas, sampling wells, and other details.

FIGURE 3.—Cracking and curling of surface mat on drying areas.

tion. Within two days after spreading the plot is sufficiently dry to permit discing and reforming for re-use. The plots of a single tract are rotated, so that each plot is spread once every six days, for a period of three months, after which another tract is used. A total of 39 in. of depth of wastes is, therefore, spread on each tract per year.

Of the total waste water applied an estimated 25 per cent is evaporated, and 30 per cent is held by the soil, leaving 45 per cent to be percolated downward. Experience shows that this depth of water is percolated away in less than 2 hr., which corresponds to a downward leaching rate of approximately 8 ft. per day.

The solids screened out at the surface dry readily to form a leathery mat, at first continuous over the ground surface, but which on drying tends to crack and curl (Figure 3). After a day or two of drying, the mat is disced under the ground, the entire area is re-leveled, and new spreading basins are reformed in preparation for the next cycle. This practice eliminates wet pockets and wet patches of mat. Following the proper number of applications in a given year, an area is no longer used for spreading, but is instead reserved for cultivation. Water for irrigating crops is obtained from wells on the site. The mat accumulations disced into the ground apparently serve admirably as fertilizer.

An alternative plan, which was considered as a means for lessening the possibility of nuisances, would have been to provide primary treatment of the wastes at the plant, to remove settleable solids and thus eliminate most of the surface mat formation. It was argued by those who were apprehensive of odor production that the deposition of settleable solids would result in conditions similar to those at the old disposal site. However, it was concluded that the plan as proposed had an excellent chance of being satisfactory without additional expenditures for pre-processing. Furthermore, were the settleable solids to be so removed, and dried, they would probably be sold locally as fertilizer, and thus would eventually be distributed over nearby lands, with probably no less chance of odor production. The plan as proposed actually accomplishes distribution of the solids by the simplest possible means and, through cropping, salvages their fertilizer value.

Spreading and Cultivation Techniques

The original plan for spreading involved the use of regular irrigation furrows, because in irrigation practice

the use of such furrows involves the least amount of work in preparing the fields for spreading, and also in cultivating and reforming them after spreading. The furrows were formed with standard discs, and were 15 to 18 in. wide and 10 to 12 in. deep.

Shortly after the use of such furrows was begun it was found that it was not possible to spread the wastes satisfactorily or to maintain the desired control over the operation. The operators were unable to prevent "losing" some of the wastes by overflow at the ends of some of the furrows. Waste waters were diverted into a series of furrows simultaneously, and because of the differences in adjacent furrows (clods, moisture content, slope, etc.) the waters did not reach the ends of the furrows simultaneously. Consequently, some of the available furrow area remained dry. Also, those furrows which were fully utilized often became ponded; in some instances the ponds broke through the ends of the furrows and spread unchecked. To prevent overflows, a terminal header was installed intersecting the ends of the furrows. However, the collected flow accumulating in this terminal header developed deposits or pockets of solid materials, which subsequently caused undesirable odors.

It was soon decided to revise the program to utilize a basin type of irrigation. Special "ridger" equipment (Figure 4) was obtained which forms elongated basins approximately 9 ft. to 10 ft. wide running the length of the tract (about 1,200 ft.). The same equipment is utilized to produce checks within the basins to slow down the flow of waste waters in each basin. Basin details are illustrated by Figures 5 and 6.

It was found that a single operator could introduce wastes into two or three of these basins at once, follow the flow down each basin, and aid or check the rate of flow if necessary. The flows reach the ends of the basins simultaneously, and overflows have been practically eliminated. Distribution of the waste waters from an irrigation header to the basins served by it is accomplished by means of an open ditch (Figure 5). Upon completing the spreading of the series of basins served by one header, the distribution ditch is covered with earth to eliminate any trapped or ponded waters.

During the past few months a third technique of spreading has been investigated, which employs "back-furrows" instead of the basins with checks. The back-furrows are ap-

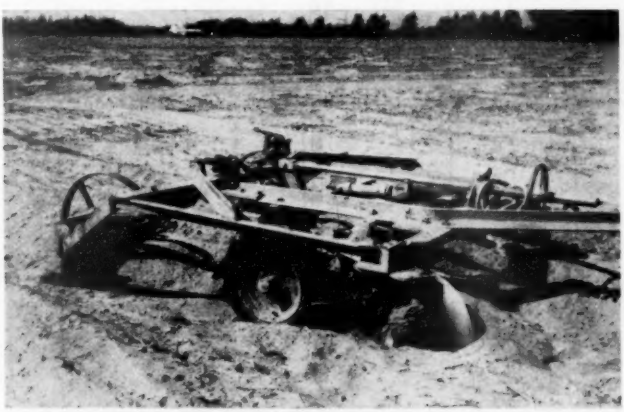

FIGURE 4.—Ridger equipment employed for forming spreading basins.

proximately 24 in. wide, and are made with a special machine which forms a path resembling a series of alternating S's and reverse S's. Thus the flow is alternately forwards and backwards, gradually progressing down the field. With this technique the time required for the flow to reach the ends of the furrows is nearly twice that to reach the ends of the basins with checks. The rate of infiltration per unit area of land is greatly increased.

It was also found that the rate of infiltration can be further increased, should this ever be necessary, by pre-wetting the land with waste water a few hours prior to spreading. However, even when the plant waste discharge is at maximum, the land is not being loaded as fully as it could be, without any pre-wetting. It has been considered better practice not to load the land to capacity, in order to facilitate a uniform operation and to minimize the possibility that the spreading operation might get out of control.

Wind Problems

Very high winds, of the magnitude of 25 to 40 mi. per hr., are not uncommon in the Ontario area during the period November through February. These result in much transport of uncovered sand exposed to the wind. Farm practices in the area generally attempt to reduce wind erosion by maintaining cover crops during the windy period, or, in the case of vineyards, by piling cuttings to form wind-breaks.

During the planning of the spreading operation there was apprehension that there would be excessive sand blowing from the tract being used for spreading, due to lack of a cover crop, especially should a high wind occur immediately following discing of a plot which had just dried. Consequently, during the windy season

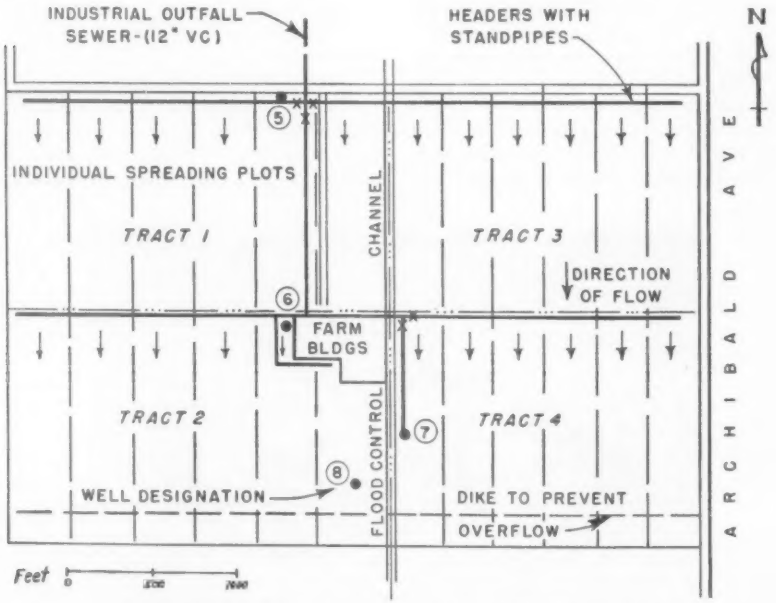

FIGURE 5.—Irrigation distribution system used for spreading.

FIGURE 6.—Spreading basins, showing division dikes and checks.

special care is taken not to disc the dried-out plots when winds are in progress or appear imminent. The previously-mentioned "crust" is allowed to remain in place, and this reduces sand blowing to a level believed to be below that occurring in the surrounding vicinity. The spreading operation is continued according to schedule, however, and sometimes this requires spreading on an undisced or crusted-over area. As already noted, the capacity of the basins to receive wastes is large compared with the loadings, so that sufficiently rapid percolation occurs even under this condition.

Odor Problems

Some of the organic particles in the waste flow settle out and accumulate in depressions and pockets, especially on the upstream side of the basin checks. Whenever the depth of these deposits exceeds about 2 in., they tend to remain moist and to produce odor nuisances, even within the short period before the plot is disced. The disposal operators are required to search out any such pockets and to cover them with earth.

Also, after spreading operations have been carried on for several months on the same tract, considerable quantities of solid materials accumulate in the terminal portion of the irrigation pipeline header. In one instance this condition was not discovered until after a sufficient odor nuisance had been produced to indicate its source. This problem has been solved by periodically flushing the header lines with well water to remove the accumulations. Blow off valves were installed to facilitate the flushing.

Insect Problems

An entomological study of insect breeding at the old disposal site on Francis Avenue showed the vinegar gnat to be the principal insect pest associated with accumulations of moist organic citrus solids. Control of this pest was scarcely possible at the old site, especially along the exposed sludge banks on the edges of the settling ponds, where intermittent wetting and drying caused the sludge to

crack and create moist interstices accessible to insects.

At the new site the measures already described, for preventing moist accumulations of solids to control odors, have also secured practical control of insect nuisances. To guarantee positive control of insect breeding, the operators have been furnished with 4-gal. pressure-type agricultural sprayers filled with DDT spray, to be used for incidental spraying, and also with a 50-gal. Hardie-type gasoline engine-driven agricultural sprayer to be utilized in case of development of a serious insect problem.

Gnat breeding has been reduced to a degree believed to be below that occurring on farms in the vicinity, even during the warm summer months. Also, because the waste waters are rapidly spread and percolate away within several hours, mosquito breeding has not been found to be of consequence. Neither has any significant fly breeding been detected.

Crop Production on Idle Areas

Upon completion of the waste-water spreading program on each of the disposal tracts, the area is planted to a suitable crop, which is irrigated with water pumped from wells on the site. If it becomes necessary to delay the sowing of the crop because of the season, the area is left fallow until ready for planting. Crops which have been planted to date on the tracts previously spread with waste waters include potatoes, field corn, sweet corn, field beans, and grains, all of which are crops commonly grown in the Chino Basin.

To date all of the crops planted on areas previously spread with waste waters have shown productions believed to be above average for the region. There has been no indication of any harmful effects due to the waste waters; instead, all indications show a very beneficial effect in increasing the yield of the crop. For example, the oat hay crops thus far produced have averaged 8 tons per acre, as compared to a normal yield for the region of approximately 5 tons per acre. Also, a recent crop of field corn planted in the two tracts east of the storm drain averaged over 20 tons of corn silage per acre, as compared to the usual yield of from 14 to 18 tons. This record substantiates previous experience gained during operation of the old disposal site, where surrounding agricultural lands were sometimes pre-irrigated with waste waters prior to the sowing of crops, with beneficial results. Such preirrigation, or rather prefertilization, was popular practice among the farmers adjacent to the disposal site, but the amount of wastes which could be thus disposed of represented only a fraction of the total.

Experiments have been made at the new site to investigate the possibilities of employing the waste waters for direct irrigation, and thus to recover the water value of the wastes as well as its fertilizer value. It was found that the high acidity of the wastes caused injury to crops, particularly to young plants. For example, when very young grain (2 to 3 in. high) was directly irrigated, some of the plants were burned out and others were seriously stunted in growth. Also, direct irrigation of a test plot of partially matured field beans, which had been previously irrigated with well water, showed a definite reduction in density of the stand, a retarding of growth, and a smaller crop of bean pods, as compared with the main crop irrigated only with well water.

Studies were made also to determine the feasibility of adding lime or other alkalies to the waste waters, to neutralize the acidity sufficiently to permit direct irrigation. The costs of neutralizing the wastes proved greater than their "water value."

Soils Study

Both the present disposal site on Edison Avenue and the former site on Francis Avenue are situated on a

broad alluvial fan within the Chino Basin, which slopes from the San Bernardino Mountains on the north southerly to the Santa Ana River. The ground slope approximates 60 ft. per mile. Depending upon location within the alluvial fan and upon proximity to drainage ways, the surface soils and subsoils vary in texture from fine sands to fine gravels. It is estimated that up to 70 per cent of the soils comprising the Chino Basin are of similar open-structured unconsolidated nature.

The soils of the 240-acre Edison Avenue site were investigated by reviewing well logs and by collecting and analyzing typical soil samples. The surface soil layer or horizon consists of a light brown to light grayish brown fine sand to fine sandy loam, which is very friable, loose-textured, and contains a considerable amount of micaceous particles and very little organic matter. This layer is 10 in. to 14 in. deep. The subsoil, extending to from 6 to 20 or 30 ft., consists of a light gray to a light grayish-brown unconsolidated fine sand, loose-textured, highly micaceous, and containing occasional seams of silt, very fine sand, and silty loam. Below 20 to 30 ft. the unconsolidated sands are interspersed with layers of silty clay and gravels. There are no impermeable clay caps, although such caps do exist in other portions of the Chino Basin.

Variations from the soil structure described occur along the storm drain dividing the farm, where the surface and subsoil horizons contain appreciable quantities of fine gravels; and in the southeast corner of the site, where from 7 to 9 ft. of unconsolidated sand overlap a calcareous silty clay loam horizon.

The soils occupying the old disposal site on Francis Avenue are similar in nature, except that the surface and upper subsoil layers consist of slightly coarser materials.

Laboratory analyses were made of soil samples collected from the 240-acre tract at depths extending from the surface down to 6 ft. The soil particles making up the unconsolidated sands (exclusive of the local gravel accumulations) have an effective size of 0.072 mm. and a porosity of from 50 to 53 per cent. Utilizing Hazen's formula for movement of water through sands, which formula is believed to be approximately applicable because the soils comprising the area are principally sands, the downward velocity is computed to be 15.8 ft. per day. However, the actual average downward velocity to the water table is estimated from field observations to be approximately 8 ft. per day. The difference is attributed to the presence of the lower silty clay layers, and also to the partial plugging effect of the suspended organic materials filtered out at the surface.

Prior to beginning waste disposal operations, samples of the upper soil layers were analyzed for organic matter content and hydrogen ion concentration. After one of the tracts has been irrigated with waste waters for three months, during which period approximately 39 in. of waste waters containing 5.2 tons of organic matter had been added per acre, the tract was left fallow for several months, after which additional soil samples and analyses were made. The results of these before and after tests showed an increase in organic matter content of only 0.13 per cent (from 0.21 per cent to 0.34 per cent) and no change in pH.

Analyses were made also of soil samples collected at the old Francis Avenue site and from the surrounding farms. These data indicate the effects of concentrated spreading over a period of 20 years, when the annual deposit of suspended solids exceeded 800 tons. The surface soils within the site had pH values of 6.2 to 6.3, compared to 6.4 to 6.5 for the surrounding areas, and an average organic content of 0.25 per cent, compared to 0.03 per cent for the surrounding areas.

Effects on Underground Waters

The ground water in the Ontario region is a portion of the large Chino Basin underground storage reservoir. It has a storage capacity in excess of 1,000,000 acre-feet, which is large compared to the annual recharge and withdrawal.

Depths to ground water at the new disposal site range from about 65 ft. at the north end of the site, to 85 ft. at the south end. Assuming a percolation rate of 8 ft. per day to be applicable over the entire depth, a minimum of eight days is required before the percolating wastes can reach the underground waters.

The organic materials of the wastes are acted upon by the natural physical, chemical, and biological processes taking place in the soil. Practically all of the suspended organic materials are presumed to be filtered out in the first few inches of topsoil. With the scheme of intermittent application employed, these materials should be readily stabilized by the great numbers of soil microorganisms present in the upper soil layers. That this actually occurs is demonstrated by the soil analyses (see previous section), which show that there has been no significant build-up of organic content in the surface soils, even at the old spreading site.

The soluble organic materials will also be acted upon and stabilized presumably in the same manner as these materials are stabilized in various secondary treatment or oxidation processes. The amount of organic matter percolating downward, measured by the soluble B.O.D., equals 9,600 lb. daily or 0.0245 lb. per square foot of land per day, applied for a total of 15 days per year. With a downward percolating path not less than 65 ft., and a minimum retention time of eight days prior to reaching ground water, the daily quantity of B.O.D. applied per cubic yard of soil will have a maximum value of 0.0013 lb. This figure compares favorably with loadings recommended for intermittent sand filters, for which approximately 0.02 lb. B.O.D. may be allowed per cubic yard per day. The data indicate that all of the organic materials are stabilized prior to reaching ground water.

Some substantiation of this conclusion was indicated by analyses of water samples drawn from eight wells located both on the downstream and upstream sides of the old heavily-dosed spreading site. The analyses included determination of the various nitrogen forms, the major cations and anions, pH, and alkalinity. The only apparent difference between the downstream and upstream data was an increase in nitrate nitrogen of from about 1.0 to 2.0 p.p.m. However, these data were considered too sketchy to be conclusive.

The quality of the underground waters may also be affected by the mineral constituents of the wastes. However, the total mineral concentration of the wastes is not excessive, the sodium ratio is low, and no particularly harmful constituents are present in significant amounts.

To establish a record of any changes in ground-water quality which might be due to spreading, especially over a prolonged period of time, routine analyses are being made of water samples taken from a series of 10 wells located as shown in Figure 2. These wells follow the direction of the ground-water flow from an area above the City of Ontario sewer farm to below the sewer farm, and thence down to the new disposal site and below it. All of these are producing wells, and draw water from depths of 100 to 400 ft. The analyses have been made at 3-month intervals. Table IV presents a summary of the data thus far available, corresponding to the first two years of operation at the new site.

The data are of particular interest because of the long history of spreading-irrigation practiced at the sewer farm. All of the sanitary sewage of the city and some of its industrial

TABLE IV.—Average Concentrations of Chemical Constituents in Test Well Waters for Period 1949–50

Constituent	Well Location and Number									
	Above Sewer Farm		Below Sewer Farm		At Spreading Site				Below Spreading Site	
	1	2	3	4	5	6	7	8	9	10
Sodium (p.p.m.)	15	17	36	26	23	23	23	18	31	29
Calcium (p.p.m.)	48	50	123	115	75	67	79	46	99	103
Magnesium (p.p.m.)	11	12	32	30	22	19	23	14	26	29
Total cations (mE./l.)	4.0	4.3	10.4	9.3	6.6	5.9	6.9	4.3	8.6	8.9
Chlorides (p.p.m.)	12	15	75	71	34	26	23	12	21	43
Alkalinity (p.p.m.)	152	171	323	275	218	204	245	167	361	320
pH	7.4	7.4	7.3	7.4	7.4	7.4	7.4	7.4	7.4	7.4
Nitrates (p.p.m.) [1]	3.5	4.8	16.6	16.1	12.0	9.5	10.2	3.8	6.4	7.7
Organic nitrogen (p.p.m.) [1]	0.7	0.5	0.3	1.2	0.9	1.0	0.7	0.9	0.8	0.9
Oxygen consumed (p.p.m.)	0.7	0.8	1.1	1.1	0.9	0.8	0.8	0.8	1.0	0.9
Boron (p.p.m.)	0.06	0.07	0.91	0.11	0.07	0.06	0.05	0.07	0.05	0.06

[1] As nitrogen.

wastes have been finally disposed of at this farm, following treatment, for a period of 36 years. The total amount of B.O.D. discharged to the sewer farm over this period is estimated to exceed 12,000 tons, applied to an area of 175 acres. The city water supply is obtained from local wells.

Comparison of the detailed analyses made over the two years have thus far shown no detectable change occurring in any of the measured constituents at any of the wells, and accordingly Table IV includes only the average data for each well. The data for chlorides, boron, and nitrate indicate that appreciable increases in these constituents are due to the sewer farm operations, but also that these increases persist only for short distances in the direction of the ground-water flow. Some increases in the metallic ions also appear to have occurred, but the data are less conclusive because of the higher figures also recorded at Wells No. 9 and No. 10, located in an area previously free from the effects of any spreading. The nitrite, oxygen consumed, and organic nitrogen data indicate complete stabilization of the applied organic matter, and the pH and alkalinity data indicate no accumulation of acidity.

Cost Data

Capital charges for establishing the 240-acre disposal site in 1948 comprised $131,000 for the land, $5,000 for buildings on the land, $2,700 for pumps and motors, $3,300 for machinery, $107,000 for constructing the 12-in. outfall sewer, and $2,600 for additional sewers at the site. These total $251,600.

Total costs for conducting the disposal operation and also for farming the idle tracts amounted to $41,000 for the year 1950. This comprised $15,300 for labor and supplies for the farming operations, $9,000 for labor and supplies for the spreading operations, $14,600 for depreciation of equipment, sewers, and other improvements, and $2,100 for consulting technical services. The personnel required for the spreading operations are a superintendent and three full-time workmen.

A sum of $20,000 was obtained from sale of the crops produced (corn, beans, and hay), which reduced the disposal costs to $21,000. This is equivalent to $0.12 per ton of fruit

processed, and to $14 per ton of B.O.D. disposed of. The costs should be less in 1951 and succeeding years through the use of the more efficient techniques developed in 1949–50. By comparison, disposal costs at the old disposal site averaged $0.13 per ton of fruit processed in 1947–48.

Summary and Conclusions

Disposal of 0.70 m.g.d. of industrial wastes containing 6 tons of B.O.D. per day has been accomplished economically and satisfactorily by spreading the untreated wastes onto porous sandy soils. Spreading basins rather than furrows are employed, in order to obtain good distribution together with positive protection against overflows. Spreading within the basins is best accomplished by use of "backfurrows," which retards the velocity of flow and thus increases the rate of infiltration.

By using ample ground area, a uniform, positive, and safe operation is assured. The wastes infiltrate into the ground readily. The suspended solids screened out at the surface form a layer thin enough to dry promptly, so that insect and odor nuisances are practically eliminated. Any organic materials reaching the underground waters appear to be completely stabilized and greatly diluted.

By using the soil alternately for spreading and cropping, much of the organic content of the wastes is reclaimed as fertilizer.

Acknowledgments

The appreciation of the authors is extended to J. A. Harmon, senior sanitary engineer, California State Department of Health. His cooperation has greatly facilitated the preparation of this discussion.

Reference

1. Rawn, A. M., Hyde, G. C., and Thomas, F., "Report Upon the Collection, Treatment and Disposal of Sewage and Industrial Wastes of Orange County, California" (July 1, 1947); abs., *Sewage Works Jour.*, **20**, 2, 351 (Mar., 1948).

STUDIES OF BIOCHEMICAL OXIDATION BY DIRECT METHODS

I. Direct Method for Determining B.O.D.*

By I. Gellman and H. Heukelekian

The standard dilution method for determining the biochemical oxygen demand (B.O.D.) of sewage and industrial wastes (17) is considered an important tool for determining the strength of wastes and the effect of their discharge on receiving bodies of water, for control of waste treatment processes, and for measurement of their efficiency. The method has several disadvantages which affect its use for studying problems concerning treatment of sewage and industrial wastes, as well as for determining their B.O.D. Among the more important are:

1. The low solubility of oxygen in water (9.2 p.p.m. in equilibrium with air, and 40 p.p.m. in equilibrium with oxygen at 20° C.) limits the range of concentration of wastes that may be studied in the standard method.

2. The determination of oxidation rates becomes a tedious matter because of the large number of bottles required.

There is a need of a direct method for continuous measurement of oxygen utilization which will enable the determination of B.O.D. and the study of various factors affecting biological oxidation of sewage and industrial wastes at concentrations similar to those encountered under treatment conditions. The term "direct method" is used to describe a method whereby the B.O.D. of a waste sample is determined by placing the sample under an atmosphere of air or oxygen in a closed system under conditions of constant agitation and temperature. The oxygen utilization is measured at any given time interval by calculating the decrease in gas volume directly or from change in pressure while maintaining constant volume. These are the basic principles governing the use of the Sierp and Warburg direct method apparatus, respectively.

There are numerous references in the literature to studies conducted with direct method apparatus of one type or another. These can be summarized in three groups, consisting of Sierp apparatus, specialized apparatus, and manometric apparatus.

In 1928, Sierp (16) developed an apparatus whereby oxygen was brought into continuous contact with the sample being oxidized and the oxygen utilization was measured by recording the change in oxygen volume in a calibrated gas burette attached to the apparatus. With minor modifications this apparatus has been used by other investigators including Cromwell (4), Buswell and Symons (18), Falk and Rudolfs (8), and Heukelekian (12). The later authors have described many useful applications of the direct method to studies other than determination of B.O.D. of sewage and industrial wastes.

Several authors have developed specialized apparatus for studying oxygen utilization by sewage-activated sludge mixtures. These include the "oxyutilometer" devised by Sawyer and Nichols (15), and the "biometer" described by Bloodgood (2). The apparatus of Theriault and Butterfield (19), and that of Grant, Hurwitz, and Mohlman (10), while of some use, are large

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and cumbersome, and do not lend themselves to replicate studies.

Manometric methods for estimating exchange of gases in biological and chemical reactions have been used for many years. Although the apparatus used differ in some ways, the basic principle involved is the same; namely, determination of gas volume changes in a closed system by measuring pressure changes at constant temperature and volume. Extensive information on the use of Warburg, Barcroft, and similar respirometers in study of bacterial and tissue metabolism may be found in two manuals on the subject by Umbreit, Burris, and Stauffer (21), and Dixon (7). Because determinations of oxygen demand of wastes are essentially measurements of rates and extent of respiration by bacterial systems, the usefulness of manometric apparatus in determining B.O.D. is readily apparent.

Investigations of sewage and sewage-activated sludge oxidations using manometric apparatus include those by Adenay (1), Wooldridge and Standfast (22) (23) (24), Langelier and Caldwell (3), and Dawson and Jenkins (5) (6). Hoover *et al.* (14) have followed the course of dairy waste oxidation using the Warburg apparatus, and Heukelekian and Gellman (9) have reported the results of a study of formaldehyde oxidation using the apparatus.

Description of Apparatus

The Sierp apparatus consists of a 300-ml. sample bottle connected to a gas burette by means of a tapered glass connection, through which runs a diffusion tube. The gas burette is calibrated in milliliters and has a capacity of 70 ml. The tapered joint also contains a glass-stoppered tube, which extends into the sample bottle almost to the bottom. This tube is used for introducing an oxygen atmosphere into the apparatus. The gas burette has two glass stopcocks at the top for refilling the burette and venting off gas from the closed system. A leveling funnel is attached to the bottom of the burette with rubber tubing. All glass joints are lubricated with silicone stopcock grease.

A mechanical shaking shelf is used to provide agitation. It consists of a motor and gear reducer unit connected to the shelf so as to provide an oscillating motion for agitation. A description of the mechanical arrangement and photographs of the apparatus are given by Falk and Rudolfs (8). The entire apparatus is installed in a walk-in 20° C. incubator. The temperature is controlled to ±0.5° C.

The Warburg apparatus consists of two sections. The sample flask is a modified Erlenmeyer flask of 140-ml. capacity, as described by Caldwell and Langelier (3). It contains an alkali well of 2-ml. capacity set in the bottom at the center. The flask mouth is tapered and of ground glass. The closed end of the manometer fits into this joint and is fitted with a three-way stopcock for venting the system. The manometer has two legs, both of which are calibrated in millimeters and are 30 cm. long. A reservoir containing the manometric fluid is attached by rubber tubing to the junction of the two legs and the fluid level is adjusted by means of a screw clamp. Glass hooks are welded into the glass at the ground joint between the flask and the manometer for attaching metal springs to hold the flask in place during an experiment. The flask and manometer combinations are mounted on an oscillating support so that the flask is completely immersed in a constant temperature bath. The bath temperature may be controlled between 10° and 50° C. (±0.1° C.) in the units containing both heater and refrigeration elements.

Methods of Calculation

The methods of calculation presented are for the purpose of converting changes in instrument scale reading to a common unit of expression; namely, p.p.m. oxygen utilized.

For the Sierp apparatus, using the following nomenclature, O_t, the oxygen utilization (in ml.) at any given time, will be

$$O_t = \left[(R_0 + V) \frac{P_0}{29.9} \frac{273}{T_0} - (R_t + V) \frac{P_t}{29.9} \frac{273}{T_t} \right]$$

Where T varies by no more than 0.5° C. the equation may be simplified to:

$$O_t = \left[(R_0 + V) \frac{P_0}{29.9} - (R_t + V) \frac{P_t}{29.9} \right]$$

The oxygen utilization in p.p.m. will then be equal (when O_t is measured at 20° C.) to:

$$\left(\frac{1{,}000}{L}\right)\left(\frac{32.0}{22.4}\right)\left(\frac{273}{293}\right) O_t = 1{,}330 \frac{O}{L}$$

where V is the gas volume in the lower chamber, in ml.; L is the liquid sample volume in the lower chamber, in ml.; P is the atmospheric pressure, in inches of Hg; R_0 is the initial uncorrected gas burette reading, in ml.; R_t is the uncorrected gas burette reading, in ml., at time t; and T is the temperature in °K.

Calculations for the Warburg apparatus are made using the following equation, in which O_t is the volumetric oxygen utilization, in cu. cm., at time t; h is the observed change in manometer scale reading, in cm., corrected for any thermobarometer reading change; V_g is the volume of gas in the closed system, in ml.; V_f is the volume of the liquid in the closed system, in ml.; and P_0 is 1 atmosphere of pressure expressed as cm. of manometric fluid—

$$P_0 = \frac{760 \times 13.6}{\text{sp. gr. of fluid}} = 1{,}001 \text{ cm. for}$$

Brodies' solution at 20° C.; T is the bath temperature, in °K.; and α is the solubility of oxygen in the liquid, expressed as ml. of gas per ml. of liquid at 760 mm. Hg and T °K.

An assumption is made that P and T remain constant during an experiment. This is rarely the case, and because the manometric fluid (Brodies' solution) is essentially water, the manometer is very sensitive to changes in atmospheric pressure and bath temperature. A thermobarometer consisting essentially of a Warburg manometer unit containing water instead of the waste sample is, therefore, used to make corrections in the observed h values for the changes due to these factors.

$$O \text{ (in cu. cm.)} = h\,k$$

where k is the "flask constant" and

$$k = \frac{V_g \frac{273}{T} + V_f d}{P_0}$$

Therefore, oxygen utilization (in p.p.m.)

$$= h\,k \left(\frac{1{,}000}{V}\right)\left(\frac{32.0}{22.4}\right) = 1{,}430 \frac{k}{V} h$$

For a given sample volume $1{,}430 \frac{k}{V}$ is a constant, which may be referred to as the "oxygen demand constant." The derivation and determination of the flask constant will be found in the manual by Umbreit (21).

Experimental Work

To adapt the two types of apparatus to measurement of oxygen demand of wastes, several problems had to be solved. These included the following:

1. Developing a modification of the Sierp apparatus to obtain complete CO_2 absorption.
2. Determining the effect of agitation on oxidation rates and measured oxygen utilization, and specification of standard agitation rates.
3. Determining sample volumes to be used, and the range of measurable oxygen demand for each apparatus.
4. Determining the degree of reproducibility.
5. Comparing the results obtained with those for the standard dilution method.

Once these problems were solved, and with the results of experiments presented in a succeeding paper, it was

possible to establish standard conditions for determining B.O.D. of sewages and industrial wastes.

Modification for Complete CO_2 Absorption in Sierp Apparatus

In measuring oxygen demand of wastes by means of either the Sierp or the Warburg apparatus, the assumption is made that any changes in gas volume or pressure during an experiment are due solely to oxygen utilization. For this to be the case, two conditions are required: (a) that only O_2 and CO_2 enter into the reaction being studied, and (b) that the CO_2 produced as an oxidation end product be completely absorbed by some alkaline agent present in the closed system. Wooldridge (22) has shown condition (a) to be the case for biochemical oxidation of sewages. Complete and rapid CO_2 absorption is effected in the Warburg apparatus by the alkali vial in the sample flask itself.

Falk (8) observed, however, that when measuring B.O.D. of industrial wastes in the Sierp apparatus, low results were obtained because of incomplete CO_2 absorption by the alkali present in the gas burette. The error was caused by the slow diffusion of CO_2 through the narrow connecting tube from the sample bottle to the gas burette. The error was found to increase with wastes of higher B.O.D. A correction curve correlating oxidation rate and CO_2 content in the gas space was suggested to overcome the error due to incomplete CO_2 absorption.

Since this type of correction was of an approximate nature, it was felt that the apparatus itself should be modified to obtain complete absorption. It was suggested that a small glass vial containing 10 ml. of 10 per cent KOH solution be attached to the lower connecting tube to bring the absorbing agent into closer contact with the waste sample undergoing oxidation.

Experiments were conducted on antibiotics waste, spent yeast nutrients, settled and unsettled paperboard mill white waters, and synthetic wastes containing 600 and 1,000 p.p.m. each of dextrose and peptone. The rates of oxidation were measured in the presence and absence of the attached alkali vial. The pH of the sample was determined at the conclusion of each experiment.

The results obtained (Table I and Figure 1) show that where the alkali vial was used the measured oxygen demand increased markedly. After 5 days the measured B.O.D. was 1.5 to 2 times as great where the vial was used. With shorter incubation periods (2 days) the differences were more marked and the measured values in the presence of the vial were 2 to 3 times as great. CO_2 analysis showed complete absorption when the vial was used. Further evidence for the improved CO_2 absorption is shown by the consistently higher pH values obtained after 5 days oxidation where the vial was used. This is caused by the lower CO_2 partial pressure above the sample, which increases the rate of CO_2 diffusion out of the liquid phase.

TABLE I.—Comparison of Measured 5-Day Oxygen Demand in Presence and Absence of Attached CO_2 Absorption Vial

Waste	Vial Present[1]	pH	Vial Absent[1]	pH
600 p.p.m. dextrose-peptone	805	—	515	—
1,000 p.p.m. dextrose-peptone	1,330	—	785	—
Anti-biotics waste	1,095	7.3	705	6.3
Settled white water	420	7.9	225	6.0
Unsettled white water	585	7.3	280	5.9

[1] Results expressed as p.p.m. oxygen demand.

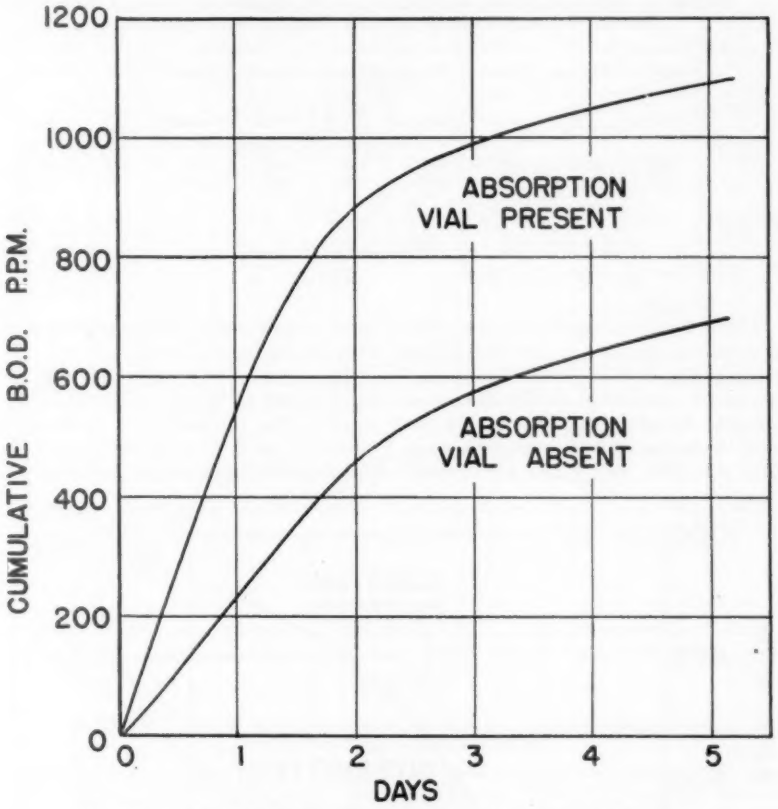

FIGURE 1.—Comparison of measured rates of oxidation for anti-biotics waste in presence and absence of CO_2 absorption vial.

Use of the absorption vial made necessary some changes in the operating technique described by Falk (8). The oxygen atmosphere is introduced through the lower connecting tube for at least 1 min. to sweep out the air originally present. A complete O_2 atmosphere is not necessary, and O_2 concentrations of close to 90 per cent were obtained in the gas phase with 1 min. of oxygenation.

The maximum sample volume must be reduced from 200 ml. to 100 ml. to prevent splashing of sample into the vial, with resultant flooding and spilling over of alkali into the sample itself.

Effect of Agitation on Measured Oxidation Rates

In the standard dilution method no provision is made for agitation, as whatever O_2 is to be utilized during the 5-day incubation is added initially with the dilution water. In determining rates and extent of oxidation by the direct method, O_2 must be provided from the gas space above the sample. Although both the Sierp and Warburg apparatus are designed for constant agitation, a study was made to determine whether this was necessary to supply the required O_2.

TABLE II.—Effect of Constant, Intermittent, and No Agitation on Measured Oxygen Demand of Sewage-Dextrose Mixtures Using the Sierp Apparatus [1]

Time (days)	Sewage +400 p.p.m. Dextrose			Sewage +800 p.p.m. Dextrose			Sewage +1,200 p.p.m. Dextrose		
	Constant	Intermittent	None	Constant	Intermittent	None	Constant	Intermittent	None
2	425	255	245	665	235	195	855	200	230
5	675	580	565	975	820	765	1,290	820	940
Final pH	7.7	7.1	6.9	7.8	6.9	6.6	7.7	6.4	6.3

[1] Results as p.p.m. oxygen demand.

Using the Sierp apparatus, the effect of constant agitation (at 240 oscillations per minute), daily shaking by hand, and quiescent incubation on the measured oxygen demand was determined for each of three samples containing sewage plus 400, 800, and 1,200 p.p.m. dextrose, respectively (supplemented with nitrogen and phosphorus).

The results (Table II and Figure 2) showed that as the initial B.O.D. of the samples was increased by addition of dextrose, so were the differences in measured oxygen demand increased be-

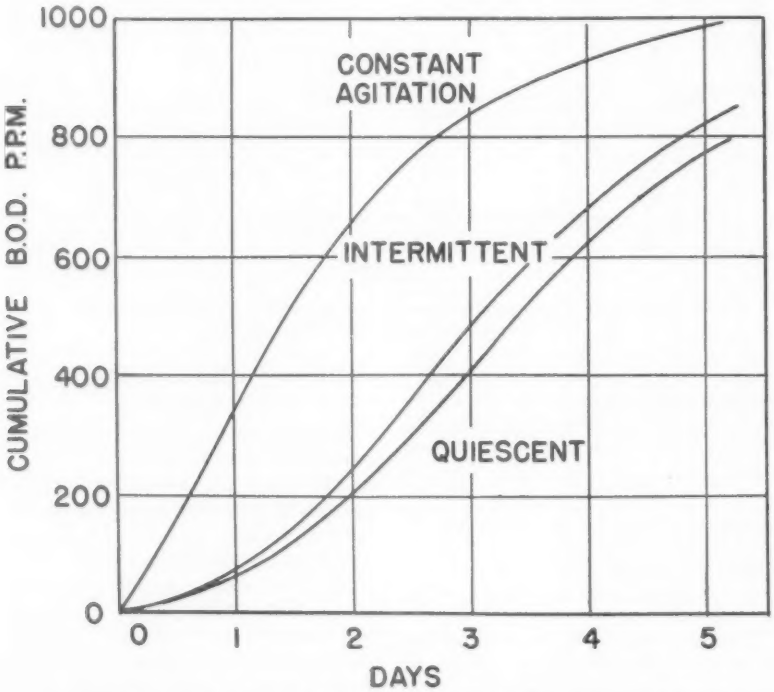

FIGURE 2.—Effect of constant, intermittent, and no agitation on measured oxygen demand of sewage containing 800 p.p.m. dextrose.

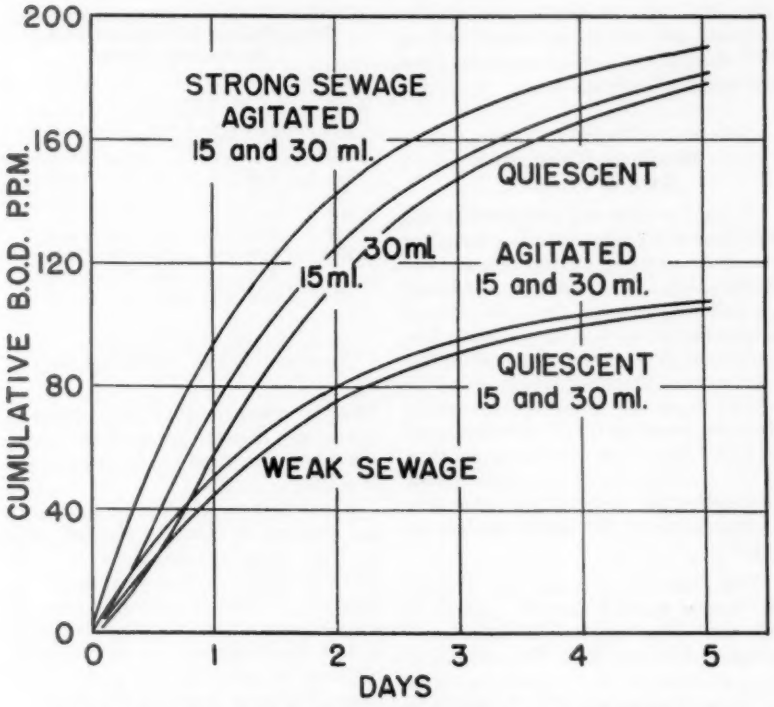

FIGURE 3.—Effect of sample volume and agitation on measured oxygen demand of strong and weak domestic sewage.

tween the constantly shaken and the remaining two samples. These differences were more pronounced after two days and were minimized as incubation proceeded toward the end of the 5-day period. Daily agitation by hand prior to measurement of oxygen demand did not result in higher measured oxidation rates than no agitation.

Where the samples received continuous agitation, the final pH was 7.7, whereas the pH was increasingly lower in the unagitated samples as the dextrose concentration was increased. This could be the result of CO_2 accumulation in the samples and is a further indication that the rate of gas transfer from gas to liquid phase and reverse was limited by the lack of agitation.

With the Warburg apparatus several experiments were conducted with domestic sewages to determine the relation between sample volume, strength, agitation, and the measured oxygen demand. It was found (Figure 3) that as the sample volume for a stronger sewage was increased, the difference in oxygen demand of shaken and quiescent samples was increased. Where differences were observed, they were greater initially and were gradually reduced as oxidation proceeded. Using a weak sewage, agitation caused no increase in the measured oxidation rate.

In general, as the strength or volume of a sewage or waste sample is increased, adequate agitation assumes greater importance. Agitation itself does not increase the rate of metabo-

lism, but only the rate of gas transfer between gas and liquid phase, and in this manner prevents O_2 supply from becoming a limiting factor.

Selection of Sample Volume, and Maximum Measurable Oxygen Demands

Several considerations enter into the selection of a proper sample volume for the direct method oxygen demand determination. The volume used must be sufficiently large that the oxygen demand equivalent of one scale reading unit is no more than 5 per cent of the total oxygen demand measured. This follows from the analytical principle that the precision of the measurement be better than, or at least equal to, that of the reaction being measured. This establishes the lowest B.O.D. that can be measured by the direct method as follows:

When the Sierp apparatus is used, the largest possible sample volume is 100 ml. The oxygen utilization is measurable to 0.5 ml. The minimum oxygen demand for a precision of 5 per cent is, therefore, 10 ml., which is equivalent to 135 p.p.m. oxygen demand at 20° C. When the Warburg apparatus is used, the largest possible sample volume is 50 ml. Since the oxygen demand is measurable to 1 mm., the minimum oxygen demand for 5 per cent precision is 20 mm., which is equivalent to 5 p.p.m. oxygen demand.

TABLE III.—Relation Between Sierp Sample Volume and Oxygen Demand Measurement Range

Sample Volume (ml.)	B.O.D. (p.p.m./ml.)[1]	Minimum Measurable B.O.D. (p.p.m.)	B.O.D. (p.p.m./60 ml.)[2]
100	13.3	133	800
50	26.7	267	1,600
25	53.4	534	3,200
10	133	1,330	8,000
5	267	2,670	16,000

[1] P.p.m. per ml. of scale reading.
[2] P.p.m. per full scale reading (60 ml.)

TABLE IV.—Relation Between Warburg Sample Volume and Oxygen Demand Measurement Range

Sample Volume (ml.)	B.O.D. (p.p.m./mm.)[1]	Minimum Measurable B.O.D. (p.p.m.)	B.O.D. (p.p.m./250 mm.)[2]
50	0.25	5	62.5
30	0.50	10	125
20	0.81	16	202
15	1.12	22	280
10	1.75	35	440
5	3.63	72	910
2	9.30	186	2,320

[1] P.p.m. per mm. of scale reading.
[2] P.p.m. per full scale reading (250 mm.)

Thus, by using the Warburg apparatus, the oxygen demand range of the standard dilution method can be approached as a limit.

The maximum measurable 1-day oxygen demand is equal to the full scale reading oxygen equivalent for the smallest sample volume used in the apparatus. Where the analyst can observe the apparatus at intervals during a day, the range can be extended by refilling the gas burette in the Sierp apparatus or by resetting the Warburg manometer.

For the Sierp apparatus, the smallest sample volume is 5 ml., for which the oxygen demand equivalent of 1 ml. change in gas volume is 266 p.p.m. For a full scale reading of 60 ml., this is equal to an oxygen demand of 16,000 p.p.m. For the Warburg apparatus, the smallest sample volume is 2 ml., for which the oxygen demand equivalent of 1 mm. change in scale reading is 9.2 p.p.m. For a full scale reading of 250 mm. this is equal to 2,300 p.p.m. oxygen demand.

From the data in Tables III and IV, a rational selection can be made of sample volume to be used. As in the standard dilution method, knowledge of the approximate oxygen demand facilitates selection of sample volume. For the Sierp apparatus the ratio of full scale reading to minimum measurable B.O.D. is 6 for all sample volumes; for

the Warburg apparatus the same ratio is 12.5. Because of these high ratios, it is usually possible to determine oxygen demand with only one sample volume.

The maximum measurable rates of oxidation are a function of the rate of oxygen diffusion into the sample during agitation. When the Sierp apparatus was used to study oxidation of waste sulfite liquor, oxygen demands of 10,000 p.p.m. B.O.D. per day were measured with a sample volume of 7.5 ml. The highest rate measured during this period was 520 p.p.m. per hour. With the Warburg apparatus, rates as high as 250 p.p.m. per hour have been recorded for formaldehyde oxidation with a 2-ml. sample volume, and 320 p.p.m. per hour for boardmill white water oxidation with a 2-ml. sample volume. That these rates are not limiting values, but are close to them, is shown by some results obtained during chemical oxygen consumed measurements for reduced sulfur compounds and waste containing ferrous iron. When 10-ml. samples are used in the Warburg apparatus with a shaking rate of 70 oscillations per minute, chemical oxygen consumed rates as high as 360 p.p.m. per hour have been recorded. Where smaller sample volumes are used, oxygen solution rates in excess of this may be expected because of the greater turbulence in the flask with smaller sample volumes. Oxidation rates as high as those mentioned are rarely encountered during measurement of normal oxygen demand and result only when acclimatized dispersed growth or activated sludge seeding is used for wastes with high B.O.D. (2,000 p.p.m. or greater), or where the waste has a chemical oxygen demand.

Determination of Degree of Reproducibility

A knowledge of the degree of reproducibility of oxygen demand measurements by means of the direct method is necessary to evaluate the significance of observed differences in oxygen demand for waste samples. Thus, if the degree of reproducibility is ± 3 per cent and two observed values differ by only 2 per cent, then the difference has no significance.

With the 10-replicate procedure suggested by Hatfield (10), the standard deviation and confidence limits were determined for three samples in the Sierp apparatus, and for one sample in the Warburg apparatus. Daily measurements were made over a 5-day period.

The waste samples used in the Sierp apparatus included a sewage-slaughterhouse waste mixture, sewage to which was added 300 p.p.m. each of dextrose and peptone, and activated sludge. The waste sample used in the Warburg apparatus was sewage to which was added 300 p.p.m. each of dextrose and peptone.

TABLE V.—Degree of Reproducibility of 5-Day Oxygen Demand Measurements by the Direct Method for Several Wastes

	Sierp Apparatus			Warburg Apparatus
	Sewage and Slaughter-house	Sewage and Dextrose-Peptone	Activated Sludge	Sewage and Dextrose-Peptone
Oxygen demand (p.p.m.)	1,065	525	1,800	513
Std. deviation, S (p.p.m.)	7	18	35	3
CL $\bar{x}$ 95% (p.p.m.)	5	13	24	2
CL x 95% (p.p.m.)	17	41	75	7
Std. deviation, S (%)	0.7	3.4	1.9	0.6
CL $\bar{x}$ 95% (%)	0.5	2.5	1.3	0.4
CL x 95% (%)	1.6	7.8	4.2	1.4

The results (Table V) include the following data:

1. The standard deviation, S, in p.p.m. of oxygen demand.
2. CL $\bar{x}$ 95 per cent (p.p.m.), or the confidence limits within which the mean of 10 determinations on a given sample will fall, as related to the mean of 10 other replicate determinations on the same sample, 95 per cent of the time.
3. CL x 95 per cent (p.p.m.), or the confidence limits within which a single value will fall for a given sample, as related to the mean of 10 replicate determinations on the same sample, 95 per cent of the time.
4. The standard deviation and confidence limits, expressed as percentages.

The standard deviation and CL x varied from 0.6 to 3.4 and 1.4 to 7.8 per cent, respectively, for the 5-day oxygen demand determination. During the 5-day period (for daily determinations) the standard deviation and CL x averaged from 2 to 4 and 4 to 8 per cent, respectively. Both the average standard deviation and CL values, as well as the range of variation, differed for different waste samples. For similar waste samples, the Warburg apparatus gave greater reproducibility than the Sierp apparatus. However, with another waste (sewage and slaughterhouse waste mixture) in the Sierp apparatus, it was possible to obtain the same reproducibility as with the Warburg apparatus.

TABLE VI.—Comparison of 5-Day Oxygen Demand Values [1] Obtained by Standard Dilution and Direct Oxygen Utilization Methods

Sample	Standard Dilution	Direct (Sierp)
Milk waste	1,090	1,100
Anti-biotics waste 1	1,450	1,095
Anti-biotics waste 2	840	750
White water 1	420	420
White water 2	580	585
White water 3	840	970
Yeast nutrients waste	720	940
Candied fruit waste	960	905
Rope cook waste	720	765
Waste sulfite liquor	1,155	1,215
Rice cooking waste	1,000	1,020

[1] Results expressed as p.p.m. oxygen demand.

TABLE VII.—Comparison of 5-Day Oxygen Demand Values [1] Obtained by Standard Dilution and Direct Oxygen Utilization Methods

Organic Compound	Standard Dilution	Warburg	Sierp
Amyl alcohol	1,230	1,590	1,540
Sodium propionate	525	590	625
Sodium oleate	1,295	1,370	1,500
Starch	515	670	710
Dextrose	640	720	775
Casein	775	895	1,010

[1] Values based on 1,000-p.p.m. concentration.

Comparison of Results of Standard Dilution and Direct Oxygen Utilization Methods

When a new method is suggested for making a determination which has formerly been made by another established method, the question immediately arises as to how results obtained with the new (direct oxygen utilization) method compare with those for the old (standard dilution) method.

Studies were made on domestic sewages, industrial wastes, and organic compounds to obtain a comparison between the two methods. The results for wastes and organic compounds are given in Tables VI and VII.

The 5-day oxygen demand of eight cotton-filtered sewage samples was determined using both the Warburg apparatus and the standard dilution method. The direct method gave results averaging 14 per cent higher (13). This applied to both the 5-day and ultimate B.O.D. values. The rate of oxidation as determined by the Thomas method (22) was the same for either method, the K-value averaging 0.26.

Table VI gives the 5-day oxygen demand measurements for 11 industrial wastes. They indicate some differences in 5-day oxygen demand values, but this difference is not consistently in

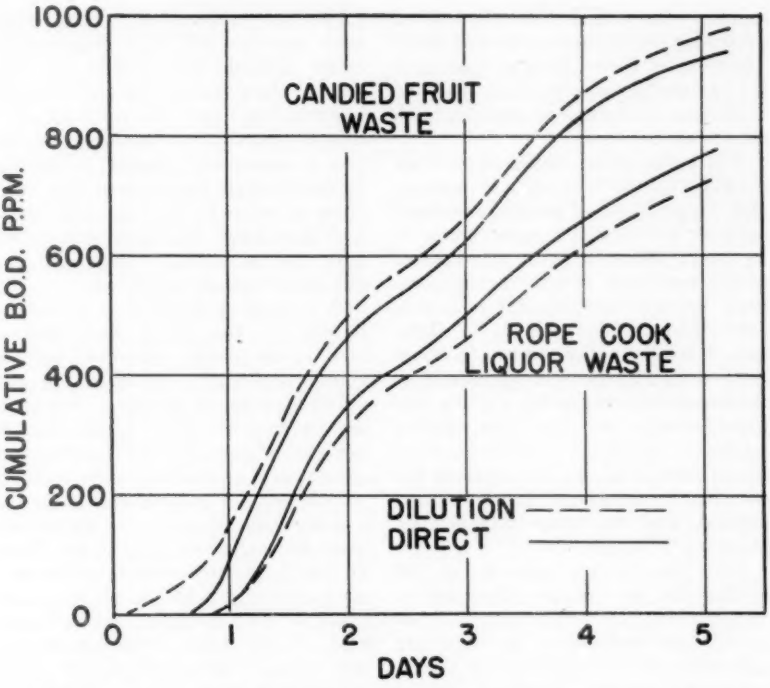

FIGURE 4.—Comparison of oxidation rates of candied fruit waste and rope cook liquor waste measured by standard dilution and direct methods.

favor of one method or the other. In general, somewhat similar results are obtained by the two methods (the average of each set of values is equal; namely, 889 p.p.m.). In Figure 4, oxidation rates are plotted for two industrial wastes—candied fruit waste and rope cook liquor waste. The curves for each waste are of similar shape, indicating little difference in oxidation rate as measured by the direct or standard dilution methods. Where there is a lag period before oxidation begins, it is encountered with either method.

Data for a group of organic compounds are given in Table VII. The Sierp and Warburg apparatus gave results consistently higher than the dilution method. The order of variation was about 20 per cent.

Discussion

By a simple modification—namely, addition of a small alkali vial—it is now possible to obtain complete CO_2 absorption in the Sierp apparatus. The error due to incomplete CO_2 absorption is avoided without resorting to a CO_2 absorption correction curve as proposed earlier. To prevent spillage of alkali into the sample during agitation, the maximum sample volume to be used must be reduced from 200 to 100 ml.

Although gas diffusion rates are sufficient for oxygen demand and measurements on dilute sewages and effluents under quiescent conditions, agitation is required in all other cases to prevent oxygen concentration in the sample from becoming a limiting factor. Agitation becomes more important as

sample volume and concentration of oxidizable organic matter are increased. Agitation of direct method apparatus is of particular importance in studying oxidations by flocculent growths, such as activated sludge.

The tables given which relate scale reading, sample volume, and measurable oxygen demand provide a rational basis for selection of sample volume to be used. Where the oxygen demand of a given waste sample is unknown, fewer different sample volumes or concentrations will be required to determine the oxygen demand by the direct method than by the dilution method, as the measurable range for a given volume is much larger than in the dilution method. In addition, the demand can be determined at any time without destroying the sample, as in the dilution method, and the range extended by rezeroing the apparatus.

With the Sierp apparatus, at 240 oscillations per minute, the highest measured oxygen demand has been 520 p.p.m. per hour; with the Warburg apparatus rates as high as 360 p.p.m. per hour have been observed with an agitation rate of 70 oscillations per minute. These rates are sufficiently high to cover any existing waste oxidation problems. Rates as high as these are encountered only with use of specialized flora, such as acclimatized dispersed growths and activated sludges, or where the waste has a high chemical oxygen utilization. Where it is desired to measure chemical oxygen utilization, the apparatus should be brought to thermal equilibrium under quiescent conditions before initial readings are made.

A comparison of degree of reproducibility data for both the direct and dilution methods indicates that both possess the same precision. Hatfield (11) reports standard deviation and confidence limits (CL x 95) ranges of 1.3 to 3.4, and 2.8 to 7.4 per cent, respectively, for 5-day oxygen demand determinations. These compare well with the results presented here of 0.6 to 3.4 and 1.4 to 7.8 per cent, respectively. Because the same reactions are being measured by either method, and because in each method the accuracy of scale reading is less than 2 per cent, it is to be expected that the degree of reproducibility of the two measurements should be similar. If the average 5-day confidence limit value of ± 5 per cent is used, it can be said that where two measured values differ by more than 5 per cent the differences become significant.

In comparing 5-day oxygen demand results for the direct and dilution methods for sewages, the direct method gives consistently higher results, the difference being 14 per cent. For single organic compounds the results were 20 per cent higher; for industrial wastes some results were higher, whereas others were lower. A possible reason for the higher results may be the higher organic concentrations used in the direct method. The oxidation rates for sewages, as expressed by the k-values, were equal for both methods, and for industrial wastes whose oxidation curves were not of the monomolecular type, similar-shaped curves were obtained for both direct and dilution method data. Again, this is to be expected, as the phenomena being measured by either method for a given waste are the same.

Summary and Conclusions

The limitations of the standard dilution method and the manner by which they are overcome with the direct method are discussed. The previous use of direct method apparatus for oxygen demand measurements is reviewed. A description of the Warburg and Sierp apparatus and the means for calculating oxygen demands are given. The results of experiments dealing with a CO_2 absorption modification for the Sierp apparatus, the effect of agitation on oxygen demand measurements, the selection of proper sample volume and establishment of measurable oxygen demand range for each apparatus, the determination of degree of reproducibility, and the comparison of results

with those for the standard dilution method, are presented.

The following conclusions were reached:

1. By insertion of an alkali vial in the Sierp apparatus, complete CO_2 absorption can be effected.

2. Agitation of both Sierp and Warburg apparatus is needed for correct oxygen demand measurement, to prevent O_2 supply from becoming a limiting factor. Agitation rates of 240 and 70 oscillations per minute are suggested for the Sierp and Warburg apparatus, respectively.

3. Rational selection of sample volumes to be used is made possible by use of proper data.

4. The highest oxidation rates measured with Sierp and Warburg apparatus are 520 and 360 p.p.m. per hour, which are considered sufficiently high to cover existing oxidation problems.

5. The degree of reproducibility is equal to that obtained with the standard dilution method.

6. Variations between observed values of less than ± 5 per cent are not significant.

7. Oxygen demand measurements may be 20 per cent higher for organic compounds with the direct method, and 14 per cent higher for domestic sewages, but the oxidation rates as expressed by K-values or as indicated by the shape of oxidation curves are equal in either method.

Based on the results presented in this and in a forthcoming paper, standard conditions for a proposed standard method for direct measurement of oxygen demand of sewages and wastes have been established. The procedure of the proposed method is given in the Appendix.

Acknowledgment

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References

1. Adenay, W. E., "The Dilution Method of Sewage Disposal." Cambridge University Press (1928).
2. Bloodgood, D. E., "Biologic Oxidation." *Sewage Works Jour.*, **10**, 6, 927 (Nov., 1938).
3. Caldwell, D. H., and Langelier, W. F., "Manometric Measurement of the Biochemical Oxygen Demand of Sewage." *Sewage Works Jour.*, **20**, 2, 202 (Mar., 1948).
4. Cromwell, E. C., "Determination of Oxygen Demand by the Direct Oxygen Method." Proc. 4th Annual Conf., Maryland Water and Sewerage Assn., p. 29 (1930).
5. Dawson, P. S. S., and Jenkins, S. H., "The Oxygen Requirements of Activated Sludge Determined by Manometric Methods." *Sewage Works Jour.*, **21**, 4, 643 (July, 1949).
6. Dawson, P. S. S., and Jenkins, S. H., "The Oxygen Requirements of Activated Sludge Determined by Manometric Methods. II. Chemical Factors Affecting Oxygen Uptake." THIS JOURNAL, **22**, 4, 490 (Apr., 1950).
7. Dixon, M., "Manometric Methods." Macmillan Co. (1943).
8. Falk, L. L., and Rudolfs, W., "Factors Affecting the Direct Oxygen Utilization Method." *Sewage Works Jour.*, **19**, 6, 1000 (Nov., 1947).
9. Gellman, I., and Heukelekian, H., "Biological Oxidation of Formaldehyde." THIS JOURNAL, **22**, 10, 1321 (Oct., 1950).
10. Grant, S., Hurwitz, E., and Mohlman, F. W., "The Oxygen Requirements of the Activated Sludge Process." *Sewage Works Jour.*, **2**, 2, 228 (Apr., 1930).
11. Hatfield, W. D., "Abstracts of Papers—Symposium on Recent Research in the Field of Water, Sewage and Industrial Wastes." Washington, D. C., U. S. Pub. Health Service (1949).
12. Heukelekian, H., "Use of the Direct Method of Oxygen Utilization in Waste Treatment Studies." *Sewage Works Jour.*, **19**, 5, 875 (Sept., 1947).
13. Heukelekian, H., and Gellman, I., "Effect of Certain Environmental Factors on the Biochemical Oxidation of Wastes" (to be published).
14. Hoover, S. R., *et al.*, "Assimilation of Dairy Wastes by Activated Sludge." THIS JOURNAL, **23**, 2, 167 (Feb., 1951).
15. Sawyer, C. N., and Nichols, M. S., "Activated Sludge Oxidations. I. Effect of Sludge Concentration and Temperature Upon Oxygen Utilization." *Sewage Works Jour.*, **11**, 1, 51 (Jan., 1939).
16. Sierp, F., "A New Method for Determining

Biochemical Oxygen Demand." *Ind. Eng. Chem.*, **20**, 247 (1928).
17. "Standard Methods for the Examination of Water and Sewage." 9th Ed. Am. Pub. Health Assn., New York, N. Y. (1946).
18. Symons, G. E., and Buswell, A. M., "Comparison of the Dilution and Absorption Methods for the Determination of B.O.D." *Ind. Eng. Chem.*, Anal. Ed., **1**, 214 (1929).
19. Theriault, E. J., and Butterfield, C. T., "Experimental Studies of Natural Purification in Polluted Waters. I. Apparatus and Technique for the Study of Biochemical and Other Oxidations in Liquids." *Pub. Health Rep.*, **44**, 2253 (1929).
20. Thomas, H. A., "Graphical Determination of B.O.D. Curve Constants." *Water and Sew. Works*, **97**, 3, 123 (1950).
21. Umbreit, W. W., *et al.*, "Manometric Techniques for Study of Tissue Metabolism." Burgess Publ. Co. (1945).
22. Wooldridge, W. R., and Standfast, F. B., "Certain Factors that Influence the Rate of Activated Sludge and Sewage Oxidations." *Biochem. Jour.*, **30**, 1, 156 (1936).
23. Wooldridge, W. R., and Standfast, F. B., "Some Experiments on the Oxidation of Sludge and Sewage Sludge Systems." *Biochem. Jour.*, **30**, 1, 149 (1936).
24. Wooldridge, W. R., and Standfast, F. B., "Use of the Barcroft Differential Manometer in the Estimation of the Oxygen Absorption of Sewage." *Biochem. Jour.*, **30**, 1, 141 (1936).

APPENDIX

Procedure for Proposed Direct Method of Determining B.O.D.

1. Reagents

1.1. Brodies' solution (manometric indicator fluid). Mix 23 g. NaCl, 5 g. bacto oxgall (sodium choleate), and Evans blue dye. Make up to 500 ml. with water for density of 1.030 at 20° C.

1.2. Alkaline CO_2 absorbent, 10 per cent KOH solution.

2. Preparation of Samples

2.1. Sewages and industrial wastes. Dechlorinate where necessary.

2.2. Industrial wastes. Neutralize the waste to pH 7 and prepare a 100-ml. sample containing 85 ml. waste, 10 ml. settled seed sewage, and sufficient nitrogen and phosphorus added as $(NH_4)_2\ SO_4$ and $NaH_2\ PO_4$ to satisfy B.O.D.:N:P ratio of 60:3:1.

3. Selection of Sample Volume

To select an appropriate sample volume for Sierp or Warburg apparatus refer to Tables III and IV of this paper.

4. Procedure

4.1. Warburg apparatus. One ml. of CO_2 absorbent is added to the center well and the desired sample volume is added to the flask. The flask is attached to the manometer and the unit is placed in a Warburg bath. The manometric fluid level is adjusted to the zero point (250 mm.) and the apparatus is equilibrated by shaking 5 min. at 70 oscillations per minute. The stopcock is then closed and the oxygen demand measured at any time interval (5 days) by reading the manometer fluid level in the open leg with the closed leg level adjusted to 250 mm. Observed pressure change is corrected for that due to variations in atmospheric pressure and bath temperature, using thermobarometer (Warburg flask containing water instead of waste sample) for the purpose. Record the pressure change in mm. of manometric fluid.

4.2. Sierp apparatus. A glass vial containing 10 ml. alkaline CO_2 absorbent solution is attached with rubber bands to the glass tube extending from the gas burette to the sample bottle. The desired sample volume is added to the bottle, and the apparatus is assembled. An oxygen atmosphere is introduced by bubbling O_2 through the sample for 90 sec. The gas burette is filled with O_2 to a level of 65 ml. The apparatus is equilibrated by shaking for 10 min. in a 20° C. room before the initial gas volume reading is taken. The oxygen demand at any time interval (that is, 5 days) is determined by measuring the apparent gas volume change in the gas burette. This is corrected for changes in barometric pressure and recorded as ml. of oxygen utilized.

4.3. Where the waste sample has a B.O.D. of less than 1,000 p.p.m., correction should be made for the B.O.D. of the sewage seeding by using a control unit containing seed alone.

5. Calculations

5.1. Warburg apparatus. Where h = total pressure change, in cm., for a given time interval, and k is the flask constant, in sq. cm.,

$$\text{p.p.m. oxygen demand} = \left(\frac{1{,}000}{\text{ml. sample vol.}}\right)\left(\frac{32 \text{ mg.}}{22.4 \text{ ml.}}\right) hk$$

5.2. Sierp apparatus. Where O = total corrected volume change, in ml., for a given time interval, then

$$\text{p.p.m. oxygen demand} = 1{,}330\left(\frac{O}{\text{ml. sample volume}}\right)$$

6. Notes

Although the method as described is for determining oxygen demand (5-day B.O.D.), it is possible to use the method as a research tool for studying the effect of various factors on the oxidation of wastes, such as:

1. Addition of nutrients (nitrogen and phosphorus).
2. Effect of seed type and concentration.
3. Determination of toxic concentrations of metals, organic compounds, and wastes by addition to sewage and observing inhibitory concentrations.

OHIO RIVER ADVISORY BOARD ON BITUMINOUS COAL

The bituminous coal industry—through its Advisory Committee to the Ohio River Valley Water Sanitation Commission—took initial steps to meet its responsibilities for alleviating stream pollution arising from coal-operating wastes at a meeting held in Cincinnati, Ohio, on August 29, 1951.

A number of committees were appointed by Chairman E. R. Price, of Wheelwright, Ky., to study problems peculiar to the industry. The two principal fact-finding committees are concerned with suspended solids and acid mine drainage. Chairmen of these committees are L. I. Cothern of Tazewell, Va., and Lawrence Cook of Cleveland, Ohio, respectively.

There is a growing concern on the part of the coal industry regarding stream pollution and the need for adoption of constructive abatement measures by the industry. The earnestness of committee members, who represent a large segment of the industry, in applying a maximum effort to cope with the existing situation was voiced.

The Advisory Committee, realizing the importance of the reduction of pollution in the streams of the Ohio valley and yet fully aware of the extreme difficulty of solving the problems facing it, expressed a desire to collaborate fully with the Commission in seeking realistic solutions. This applies particularly to acid mine drainage, discoloration of the discharge from mines, and fine solids from mining activity that are carried along by the streams.

The Advisory Committee is made up to two representatives from each of these states: Virginia, Pennsylvania, West Virginia, Kentucky, Ohio, and Indiana.

EFFECTS OF SOME CHEMICALS USED IN OIL WELL DRILLING ON MARINE ANIMALS

By F. M. Daugherty, Jr.

Marine Laboratory, Texas Game, Fish and Oyster Commission

With the recent increase of oil wells in Texas bays, the possibility of pollution from chemical compounds used in drilling became important. Exact knowledge of the effect of these compounds on marine organisms was needed. Seventeen of the commercial products used in drilling were tested.

Apparatus and Procedure

Two testing systems were used in the experiment. Battery jars of 30-l. capacity served as aquaria.

The first, a simple circulating system, consisted of eight jars set in series on 4-in. risers (Figure 1). Plastic siphon tubes connected the jars in series and water was carried from bottom to top by means of a stainless steel pump. Flow was regulated by means of a single "Hoffman" clamp on the pump suction tube. This circulation, coupled with agitation caused by stone air-breakers, induced a complete mixing and circulation cycle in 40 min. The entire system contained 250 l. of sea water. Different species of test animals were placed in each jar and allowed an acclimatization period of 24 hr. After this period, premixed or dissolved test materials were introduced on a parts per million basis and increased in concentration at 40-min. intervals. Salinity, pH, and temperatures were checked before and after the acclimatization period and at the time of each increase in concentration. Specimens were observed for any unusual activities and death times were recorded. An identical system was used as a control.

The second testing system, noncirculating, consisted of a series of battery jars containing a like number and species of test animals (Figure 2). As in the circulating system, an acclimatization period of 24 hr. was allowed. Test materials were then introduced in series covering the suspected lethal range. Materials were premixed or dissolved and then introduced directly into the air stream from the stone air-breaker. A jar containing like species was used as a control. Physical data, unusual actions, and deaths were noted as in the circulating system.

Concurrent Work

Simultaneously, experiments using oil well drilling compounds were started at the University of Texas by A. W. Anderson and at Our Lady of the Lake College by Sister Mary Berenice. Fresh-water species were used as test animals. The equipment employed was the same as that used by the writer. The results of this work have been treated elsewhere.

Toxicity of Drilling Compounds

The test materials have been divided into three categories according to their relative toxicity. The nontoxic group is comprised of those substances which did not kill any test animals. The low-toxicity group killed some test animals in concentrations of 500 to 7,500 p.p.m. The third or toxic group killed most test animals in 70 to 450 p.p.m. None of the compounds tested could be considered as high-toxicity agents.

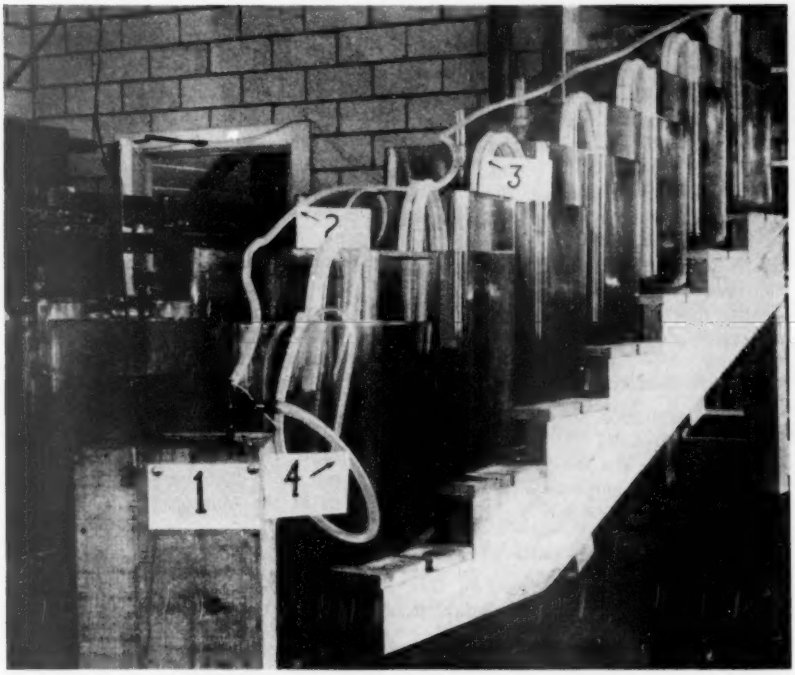

FIGURE 1.—Circulating test systems, showing:
1. Stainless steel pump for circulating water in aquaria.
2. Pump discharge to top aquarium.
3. Siphon tubes carrying water through aquarium series.
4. Pump intake from bottom aquarium.

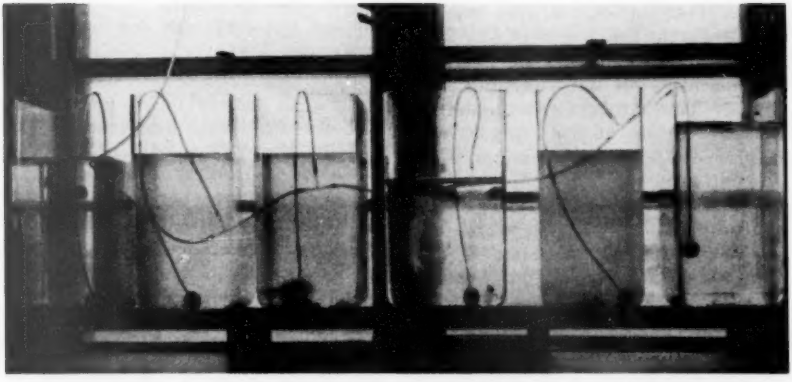

FIGURE 2.—Non-circulating test system supplied with aeration bulbs.

Non-Toxic Compounds

Baroco drilling clay, Baroid drilling mud, Aquagel, Carbonox, Jelflake, Fibertex, Mica, and Oilfos have been considered as non-toxic, due to their failure to kill test animals in concentration as high as 7,500 p.p.m. A single *Cynoscion nebulosus* died in a 6,000-p.p.m. concentration of Aquagel in 22 hr.; however, the cause of this death was questionable. No observations were made on the possibility of deaths due to accumulation of these materials on the bottom.

Low-Toxicity Compounds

Five compounds which were toxic in concentrations of 500 to 7,500 p.p.m. are included in the low-toxicity group. Some of these compounds were fatal to oysters, but not to fish.

Sodium Acid Pyrophosphate

Circulating test system:—Two *Galeichthys felis*, 3 *Mugil cephalus*, 2 *Orthopristis chrysopterus*, 3 *Lagodon rhomboides*, 2 *Archosargus probatocephalus*, 2 *Cynoscion nebulosus*, 2 *Bairdella chrysura*, 2 *Sciaenops ocellatus*, *Micropogon undulatus*, 8 *Penaeus* spp., 4 *Callinectes sapidus*, and 24 *Ostrea virginica* were used as test animals. Deaths occurred in concentrations of 2,500 to 9,500 p.p.m. with a pH range of 4.3 to 3.6. *G. felis* was the most resistant fish, one requiring 9,500 p.p.m. for killing. All other fish died in concentrations not exceeding 3,000 p.p.m. Three oysters recovered from a concentration of 9,500 p.p.m. with a pH of 3.6. The minimum lethal concentration was 2,500 p.p.m. within 4.5 hr. There were no deaths in the control.

Non-circulating test system:—Fourteen *Galeichthys felis*, 14 *Lagodon rhomboides*, 10 *Cynoscion nebulosus*, 10 *Sciaenops ocellatus*, 14 *Penaeus* spp., and 14 *Ostrea virginica* were used as test animals in a seven-aquarium system with concentrations ranging from 500 to 3,500 p.p.m. All *S. ocellatus* (juvenile forms) were dead in 20 to 70 min. in concentrations of 1,000 to 3,500 p.p.m. Other specimens used were adult forms, which showed rather erratic tolerances to the various concentrations, with deaths occurring in a range of 30 min. to 44 hr. All test animals, with the exception of one *Penaeus* spp. which survived 2,000 p.p.m., were killed in concentrations in excess of 1,500 p.p.m. One *L. rhomboides* and one *G. felis* survived 1,500 p.p.m. for 44 hr.; 1,000 p.p.m. was fatal for all species. One specimen each of *G. felis*, *L. rhomboides*, and *O. virginica* survived 500 p.p.m. for 44 hr. All test animals surviving 44 hr. recovered completely. The minimum lethal concentration was 500 p.p.m. in 20.5 hr. No deaths occurred in the control.

Quadrafos

Circulating test system:—Unfortunately, the data on the species of fish used in the Quadrafos test were lost and there was not sufficient time to rerun the experiment. It was noted that all fish survived 72 hr. with the concentration increased regularly until 3,500 p.p.m. was attained. Data reveal that 20 out of 24 *Ostrea virginica* were killed in 72 hr. with the concentration up to 3,500 p.p.m. There were no deaths in the control. No test was made with a non-circulating system.

Impermex

Non-circulating test system:—Three *Orthopristis chrysopterus*, 9 *Lagodon rhomboides*, 3 *Bairdella chrysura*, and 6 *Ostrea virginica* were tested in concentrations of 1,000, 3,000, and 5,000 p.p.m. All fish survived all concentrations for 96 hr. and recovered completely. *O. virginica* survived 1,000 p.p.m. for 96 hr., but were killed in 3,000 and 5,000 p.p.m. within 96 hr. No deaths occurred in the control. Impermex was not tested in a circulating system.

Sodium Polyphosphate

Circulating test system:—Two *Galeichthys felis*, 1 *Mugil cephalus*, 3 *Orthopristis chrysopterus*, 2 *Lagodon rhomboides*, 1 *Archosargus probatocephalus*, 1 *Cynoscion nebulosus*, 1 *Sciaenops ocellatus*, 2 *Micropogon undulatus*, 1 *Menticirrhus americanus*, 1 *Pogonius cromis*, and 24 *Ostrea virginica* were tested in concentrations increased to 1,500 p.p.m. within 21 hr. The experiment was continued through 45 hr. with no increase in concentration. The first deaths occurred in 21 hr. All *G. felis*, *M. cephalus*, *O. chrysopterus*, *S. ocellatus*, *M. americanus*, *O. virginica*, and 1 *L. rhomboides* survived 45 hr. All other specimens were killed within 45 hr. with a pH change of 7.8 to 4.6. The minimum lethal concentration was 1,500 p.p.m. within 20.5 hr. No deaths occurred in the controls.

Non-circulating test system:—Fourteen each of *Galeichthys felis*, *Lagodon rhomboides*, *Micropogon undulatus*, and *Ostrea virginica* were tested in concentrations ranging from 500 to 6,000 p.p.m. All *G. felis* in 500 p.p.m. were dead within 22 hr., but those in greater concentrations survived 28 hr. and recovered. One *L. rhomboides* in 3,500 p.p.m. and all in 1,000 p.p.m. survived 28 hr., while total deaths occurred at all other concentrations within this time. The minimum lethal concentration was 500 p.p.m. in 2 hr. *O. virginica* survived all concentrations except 1,500 p.p.m., in which both specimens died within 28 hr. One *M. undulatus* survived 1,500 p.p.m. for 28 hr., while other concentrations were fatal within this time. The minimum lethal concentration was 500 p.p.m. in 2 hr. There were no deaths in the controls.

Stabilite No. 9

Circulating test system:—One *Caranx hippos*, 2 *Orthopristis chrysopterus*, 2 *Lagodon rhomboides*, 1 *Cynoscion nebulosus*, 1 *Leiostomus xanthurus*, 1 *Pogonias cromis*, 1 *Chaetodipterus faber*, 2 *Stephanolepis hispidus*, 1 *Nautopaedium porosissimus*, and 16 *Ostrea virginica* were tested in concentrations up to 600 p.p.m. for 94 hr. *P. cromis*, *N. porosissimus*, and one each of *O. chrysopterus* and *L. rhomboides* survived concentrations up to 600 p.p.m. for 94 hr.; all but one *O. virginica* survived this time and concentration. All other specimens were dead within 94 hr. The minimum lethal concentration was 500 p.p.m. within 46 hr. No deaths occurred in the controls.

Non-circulating test system:—Nine *Lagodon rhomboides* and 6 *Ostrea virginica* were tested in concentrations of 1,000, 3,000, and 5,000 p.p.m. for 96 hr. All *L. rhomboides* were dead in 1 hr., and all *O. virginica* within 96 hr. The minimum lethal concentration was 1,000 p.p.m. in 1 hr. There were no deaths in the controls.

Toxic Compounds

Four compounds, which were usually lethal in concentrations of 70 to 450 p.p.m., have been designated as toxic. These materials were more toxic to fish than to oysters.

Caustic Soda

Circulating test system:—*Two Mugil cephalus*, 3 *Orthopristis chrysopterus*, 3 *Lagodon rhomboides*, 1 *Archosargus probatocephalus*, 2 *Cynoscion nebulosus*, 1 *Sciaenops ocellatus*, 1 *Pogonias cromis*, 5 *Penaeus* spp., and 24 *Ostrea virginica* were tested in concentrations increased to 180 p.p.m. within 23 hr. All *M. cephalus*, *A. probatocephalus*, *P. cromis*, and *O. virginica* survived this time and a pH of 12.0. All other specimens were killed. The minimum lethal concentration was 90 p.p.m. within 4.5 hr. No deaths occurred in the controls.

Non-circulating test system:—Fourteen each of *Galeichthys felis*, *Lagodon rhomboides*, *Cynoscion nebulosus*, *Penaeus* spp., and *Callinectes sapidus* were

tested in concentrations ranging from 50 to 200 p.p.m. for 21 hr. *G. felis* survived 50, 160, and 200 p.p.m. for 21 hr., but were killed in all other concentrations. *L. rhomboides* were killed in all concentrations except 50 and 70 p.p.m. *C. nebulosus* survived 50, 70, and 120 p.p.m., but were killed in all other concentrations. *Penaeus* spp. were killed in all concentrations except 50 p.p.m. *C. sapidus* were killed in all concentrations except 50, 120, and 200 p.p.m. The minimum lethal concentration was 70 p.p.m. in 5 hr. There were no deaths in the controls.

Oil Well Cement

Circulating test system:—One *Galeichthys felis*, 3 *Fundulus grandis*, 2 *Orthopristis chrysopterus*, 1 *Bairdella chrysura*, 2 *Sciaenops ocellatus*, 2 *Micropogon undulatus*, 2 *Menticirrhus americanus*, 2 *Prionotus* sp., 1 *Ancylopsetta quadrocellata*, 1 *Achirus fasciatus*, and 24 *Ostrea virginica* were tested in concentrations increased to 650 p.p.m. within 22 hr. All *G. felis*, *F. grandis*, *A. fasciatus*, and *O. virginica* survived 650 p.p.m. and 22 hr. Other specimens tested were dead in 550 p.p.m. and 6.5 hr. The minimum lethal concentration was 300 p.p.m. within 3.5 hr. No deaths occurred in the controls.

Non-circulating test system:—Fourteen *Micropogon undulatus*, 7 *Menticirrhus americanus*, and 21 *Ostrea virginica* were tested in concentrations ranging from 100 to 400 p.p.m. for 22.5 hr. All concentrations were fatal to *M. americanus* within 3 hr. All *M. undulatus* survived 100 and 150 p.p.m. and one was not killed by 300 p.p.m. Other concentrations were fatal within 22.5 hr. *O. virginica* were not affected by any concentration for 22.5 hr. The minimum lethal concentration was 100 p.p.m. in 3 hr. There were no deaths in the controls.

Tannex

Circulating test system; first test:—Two each of *Fundulus grandis*, *Cyprinodon variegatus*, *Orthopristis chrysopterus*, *Lagodon rhomboides*, *Archosargus probatocephalus*, *Cynoscion nebulosus*, *Pogonias cromis*, and *Spheroides* sp.; 8 *Penaeus* spp., and 24 *Ostrea virginica* were tested in concentrations increased to 140 p.p.m. within 22.5 hr. All fish were dead within 22.5 hr. with a minimum lethal concentration of 100 p.p.m. within 4 hr. All *Penaeus* spp. and *O. virginica* survived 22.5 hr. with concentrations increased to 140 p.p.m. No deaths occurred in the controls.

Circulating test system; second test:—Two each of *Mugil cephalus*, *Orthopristis chrysopterus*, *Lagodon rhomboides*, *Sciaenops ocellatus*, *Leiostomus xanthurus*, *Micropogon undulatus*, *Chaetodipterus faber*, *Chilomycterus schoepfi*, and *Prionotus* sp.; and 24 *Ostrea virginica* were tested in concentrations increased to 450 p.p.m. within 20.5 hr. All fish were dead within 20.5 hr., whereas all oysters survived. The minimum lethal concentration was 150 p.p.m. within 2 hr. No deaths occurred in the controls.

Non-circulating test system:—Fourteen each of *Mugil cephalus*, *Lagodon rhomboides*, and *Cynoscion nebulosus* were tested in concentrations ranging from 10 to 100 p.p.m. for 23 hr. *M. cephalus* were only killed in 80 p.p.m. for 3.5 hr., which was the minimum lethal concentration. *L. rhomboides* were only killed in 90 and 100 p.p.m. and *C. nebulosus* only in 100 p.p.m. There were no deaths in the control.

White Lime

Circulating test system:— One *Dasyatis sabina;* two each of *Galeichthys felis*, *Lagodon rhomboides*, *Archosargus probatocephalus*, *Cynoscion nebulosus*, *Sciaenops ocellatus*, *Leiostomus xanthurus*, *Menticirrhus americanus*, and *Prionotus* sp.; 8 *Penaeus* spp., and 24 *Ostrea virginica* were tested in concentrations increased to 210 p.p.m. within 4.5 hr. All *D. sabina*, *G. felis*, and *O. virginica* survived 210 p.p.m. and 18 hr., as did one *A. probatocephalus.*

All other fish were dead within 18 hr. The minimum lethal concentration was 130 p.p.m. within 2 hr. No deaths occurred in the controls.

Non-circulating test system:—Fourteen each of *Galeichthys felis, Orthopristis chrysopterus, Lagodon rhomboides, Penaeus* spp., and *Ostrea virginica* were tested in concentrations ranging from 75 to 225 p.p.m. for 23.5 hr. All *G. felis, Penaeus* spp., and *O. virginica* survived the test. *O. chrysopterus* survived 75, 100, and 125 p.p.m. for 23.5 hr., but were killed in all other concentrations. *L. rhomboides* were killed in 150 and 225 p.p.m., but survived all other concentrations for the duration of the test. There were no deaths in the control.

Summary

1. Baroco drilling clay, Aquagel Baroid drilling mud, Carbonox, Jelflake, Fibertex, Mica, and Oilfos had no lethal effect on any test animal; therefore, they have been designated as non-toxic materials.

2. Sodium acid pyrophosphate, Quadrafos, Impermex, sodium polyphosphate, and Stabilite No. 9 were toxic to some test animals in concentrations ranging from 500 to 7,500 p.p.m. These compounds have been designated as low-toxicity materials.

3. Caustic soda, oil well cement, Tannex, and white lime were fatal to many test animals in concentrations ranging from 70 to 450 p.p.m. These compounds have been designated as toxic materials.

4. In general, it seems that low-toxicity compounds were more effective on oysters than on fish, whereas the converse was true for toxic materials.

5. Although it is possible to establish tentative safe levels based on concentrations below the minimum lethal concentrations, there are certain aspects of these tests which can be questioned. Non-circulating tests are probably more accurate than the circulating tests. The tests were too generalized and toxic levels were not narrowed sufficiently. Too many species of test animals and too few of each species were used. It is apparent, however, that the compounds tested were sufficiently low in toxicity to be of little danger when released in open bay waters.

EVALUATION OF METHODS FOR MEASUREMENT OF FREE CYANIDE *

By Edgar G. Will

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Because of the great interest in stream pollution by cyanide wastes, much has been done and much written concerning the disposal of these wastes. They are usually complex mixtures of metals and cyanides, and a number of methods have been devised to dispose of them. Also, there are a number of methods aimed at the measurement of the amount of free or loosely combined cyanide. By "*free*" is meant the normal salts of HCN, as well as any HCN present. Methods have been selected and modified to meet the demands of the wastes to be analyzed, and thus may not apply to other types of cyanide wastes. In attempting to check other analyses and other methods, differences were noted which could not be readily explained; therefore, an evaluation of a few of the methods was undertaken.

The methods selected and compared on known samples were:

1. The pyrazalone-pyridine method, using chloramine T and pyrazalone reagent.
2. The pyridine-benzidine method of Aldridge, using bromine and pyridine-benzidine reagent.
3. The phenolphthalin method, using phenolphthalin and KOH.
4. The modified Liebig method, using silver nitrate with an internal indicator.

These methods were used on KCN alone and on mixtures of KCN with cyanates, with thiocyanates, with ferri- and ferrocyanides, and with nickelocyanide complex. The mixtures were also distilled and the distillates tested, in order to determine what the methods measured, and the interference, if any. Temperature and pH play an important part in the preservation of the cyanide from the time of sampling until analysis, as well as in holding the original composition. Aeration should be avoided during sampling because of the loss of HCN, and the pH should be adjusted to between 11 and 12 with NaOH, taking care not to add a large excess of alkali, as this may break down some of the complexes, such as cadmium and zinc, changing them to sodium cyanide, thus increasing the so-called free cyanide. Cyanogen chloride may be formed by the reaction of chlorine in alkaline solution, though normally cyanates are formed. Refrigeration should be used on all samples held in the laboratory. With this care most samples will remain relatively stable for several weeks.

Liebig Method

The Liebig method, one of the oldest, has a number of modifications. The method is essentially titration in alkaline solution with silver nitrate. It is based on the fact that silver nitrate forms a soluble double cyanide with an alkaline cyanide, further addition of silver nitrate causing a permanent turbidity. Because of the difficulty of reading the faint turbidity, this method requires a clear sample, which is not always available. Filtration, being attendant with possible loss of HCN (as well as oxidation), does not prove satisfactory.

The modified Liebig method suggested by Ryan and Culshaw was selected because they used an internal

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indicator (p-dimethyl amino benzyl rhodanine), which forms colored salts with silver and certain heavy metals. In slightly alkaline medium there is little interference—even large amounts of chloride do not interfere—and the color change is quite distinct, changing from yellow to salmon. With 1/1000 N silver nitrate solution, which should be freshly prepared, and 0.02 per cent p-dimethyl amino benzyl rhodanine in acetone, the procedure is simply to adjust the pH to between 10 and 11, and using 8 drops of indicator per 100 ml., titrate with the silver nitrate to a salmon pink, using a blank for comparison. This method will measure from 0.1 p.p.m. up, and was found to be very dependable. It seemed to be the first choice of many workers. The method measures so-called free cyanide only. The cyanates, thiocyanates, and metal complexes are not measured by the titration. Sulfides and a large excess of alkali should be avoided, as they give high results. It was also noted that free chlorine interfered and gave high results.

Phenolphthalin Method

The phenolphthalin method, using dilute potassium hydroxide and an alcohol solution of phenolphthalin in dilute copper sulfate solution, was selected and found very acceptable both as to simplicity and accuracy. Here again, it was found that the pH must be corrected for concordant results. The pH should be adjusted to between 7.5 and 8. The reagents used are 0.05 per cent KOH solution, 1 per cent phenophthalin in 0.6 per cent KOH as stock dilution, and a phenolphthalin solution of 0.5 ml. of stock solution in 99.5 ml. of 0.01 per cent copper sulfate. This working solution should be made fresh every three days. The procedure was to place 1 ml. of KOH solution in a test tube and add 2 ml. of the sample (adjusted for pH) and 1 ml. of phenolphthalin reagent; mix and compare after 10 min. Read at 525 millimicrons, or compare visually with standards.

This method will measure from 0.5 to 10 p.p.m. without dilution, and was found to be quite dependable, with the exception that in the presence of ferricyanides the method includes 20 to 30 per cent of the ferricyanide, possibly due to some side reaction. It does not measure cyanate, thiocyanate, ferrocyanide, or nickel complex. It was noted that low results were obtained with some alkali preserved wastes unless the settled or centrifuged samples were used.

Thus, it is seen that this method measures free cyanide plus part of any ferricyanide present. It was noted that many authors used phenolphthalin for this test. Although that chemical will measure cyanides, it is relatively insensitive and has different properties, and is not recommended.

Pyridine-Benzidine Method

The pyridine-benzidine method of Aldridge has been recommended, and while requiring more manipulation, is favored by many workers. The method depends on the formation of cyanogen bromide in acid solution and the formation of a red color, with the pyridine-benzidine mixture. This method gave concordant results and although not as simple as the above method, gave reliable results if the method was followed carefully and the volumes stated were used. The reagents required are 10 per cent acetic acid, bromine water, 1.5 per cent aqueous solution of sodium arsenite, 2 per cent benzidine HCL, and 2 per cent HCL in pyridine. The procedure is as follows: Acidify 2 ml. of sample to a pH of 5 with acetic acid; add 2 drops of bromine water and mix; destroy the excess bromine with 0.2 ml. of arsenite solution; add 3 ml. of pyridine HCl solution, mix, and let stand 15 min.; dilute to 25 ml.; and read after 10 min. standing, using a wavelength of 520 millimicrons on the spectrophotometer.

This method determines free cyanide and thiocyanates. Cyanates and metal complexes are not measured. The method will determine from 0.25 to 4 p.p.m. if extreme care is given to all steps in the procedure. Large amounts of copper, lead, or zinc will interfere with this method.

Pyrazalone Method

The pyrazalone method of Epstein was also checked. In this method the cyanogen chloride formed gives pyridine glutaconic aldehyde, which forms a blue dye with pyrazalone. This method has the advantage of being simple and easy to operate. It requires approximately one-half hour to complete, and the sensitivity is good. The reaction may be carried out with a pH of from 3 to 9. Above pH 9 the results are inaccurate, and are entirely too low. The reagents used are 1 per cent solution of chloramine T and the pyridine-pyrazalone reagent, consisting of 4 per cent solution of phenyl-methyl-pyrazalone with 0.08 per cent of bis-pyrazalone dissolved in pyridine. This solution should be freshly prepared every week. The bis-pyrazalone must be prepared by refluxing 17.4 g. of phenyl-methyl-pyrazalone dissolved in 100 ml. of alcohol with 25 g. of freshly distilled phenyl-hydrazine for 4 hr. The bis-pyrazalone is then filtered hot and washed with alcohol. The procedure is as follows: To 10 ml. of sample adjusted for pH, add 2 ml. of chloramine T solution, and mix; after exactly 1 min. add 3 ml. of pyridine-pyrazalone reagent, and mix; measure the transmittancy after 20 min. at 630 millimicrons. As little as 0.2 micrograms can be measured by this method, with an accuracy of 5 per cent, or from 0.02 to 0.8 p.p.m. without dilution. The method measures free cyanide only, although thiocyanates may be measured by a modification of the method; however, cyanates and metal complexes are not measured by this method.

Comparison of Distillates

It may be necessary for clarification and concentration of the sample to make a distillation. Therefore, a comparison of distillates was also made, using a 500-ml. sample neutralized to methyl orange; then 1 ml. of 15 per cent tartaric acid was added and 200 ml. of sample was distilled into 50 ml. of 0.1 N NaOH. An all-glass still was used, making sure the condenser tube dipped below the surface of the NaOH. In checking the various methods with distillates of 1 p.p.m. KCN plus 1 p.p.m. of cyanate, thiocyanate, and metal complexes, all of the methods gave excellent recovery measurements within 5 per cent; but it was noted that cyanates and thiocyanates did not break down or distill over upon distillation with tartaric acid. The metal complexes did break down, and the HCN formed distilled over 100 per cent, thus increasing the apparent free cyanide content.

Summary

Preservation of the free cyanide in the sample with alkali, proper adjustment of the pH during the determination, and attention to the effect of metal complexes will do much to give uniformity of results on cyanide wastes. Filtration will cause a loss of cyanide in some cases, and it has been found that centrifuging for 10 min. will clarify most samples without a loss of cyanide. This is recommended, as it removes many interfering metals, especially in alkaline solution, and leaves a clear sample to work with. Refrigeration of the sample at pH 11 for 12 hr. will usually cause the suspended solids to settle out, and may be more convenient than centrifuging if time need not be considered.

The various methods evaluated were primarily designed for the measurement of free cyanide, and by careful work they all do an excellent job; nevertheless, it is only by the same careful handling of the sample that concordant results may be had.

COLOR IN INDUSTRIAL WASTES

II. DETERMINATION BY FILTERPHOTOMETRIC METHOD *

By Willem Rudolfs and William D. Hanlon

In a previous paper (2), a method was described for the determination of industrial waste color characteristics by utilizing selected light transmission data obtained with a spectrophotometer. It is the purpose of this paper to present a simplified, less costly, alternate, filterphotometric method for the determination of industrial waste color characteristics in terms of dominant wavelength, luminance, and purity.

The tristimulus values (X, Y, and Z) represent the respective amounts of the three International Commission on Illumination (I.C.I.) primaries ($\bar{x}$, $\bar{y}$, and $\bar{z}$) necessary to match the color of a waste sample when illuminated by standard illuminant C. If a light source is available which has a relative energy distribution similar to that of one of the I.C.I. primaries when weighted with illuminant C, it is possible to determine the percentage of this primary that will be transmitted by a waste sample. The percentage transmission value when multiplied by the total color contribution for the corresponding I.C.I. primary (weighted with illuminant C) gives the tristimulus value for the selected primary. This procedure may be repeated to obtain tristimulus values for each of the two remaining primaries. The tristimulus values are converted to trichromatic coefficients in the same manner as described for the spectrophotometric method (2).

Specifications for Tristimulus Filters

To determine the specifications for the three required tristimulus light filters, it was necessary to have the following data:

1. Energy distribution data for I.C.I. illuminant C.
2. Tristimulus values for the I.C.I. primaries ($\bar{x}$, $\bar{y}$, $\bar{z}$).
3. Relative energy distribution data for the filterphotometer light source.
4. Relative sensitivity data for the filterphotometer photoelectric cell.

The tristimulus values for the I.C.I. primaries ($\bar{x}$, $\bar{y}$, and $\bar{z}$) when weighted with the energy distribution for illuminant C (Ec) were obtained from Hardy's "Handbook of Colorimetry" (1). Curves representing these values are shown in Figure 1.

Because a Fisher electrophotometer was available, the tristimulus filter specifications were determined on the basis of the light source and photoelectric cells in this instrument. The relative spectral energy distribution curve for the tungsten light source at 3,000° K. is shown in Figure 2, and the relative sensitivity curve for the photoelectric cell in Figure 3.

The most important requirement for the tristimulus filters is the shape of the respective transmission curves. The total amount of light energy transmitted by the filters is important only in relation to adequate energy for the effective operation of the photoelectric cell. Once the tristimulus light requirements (Figure 1) are available, it is possible to calculate the light filter requirements, which, combined with the data for the light source (Figure 2) and the photoelectric cell (Figure 3), give the desired tristimulus light characteristics. The relative light transmission

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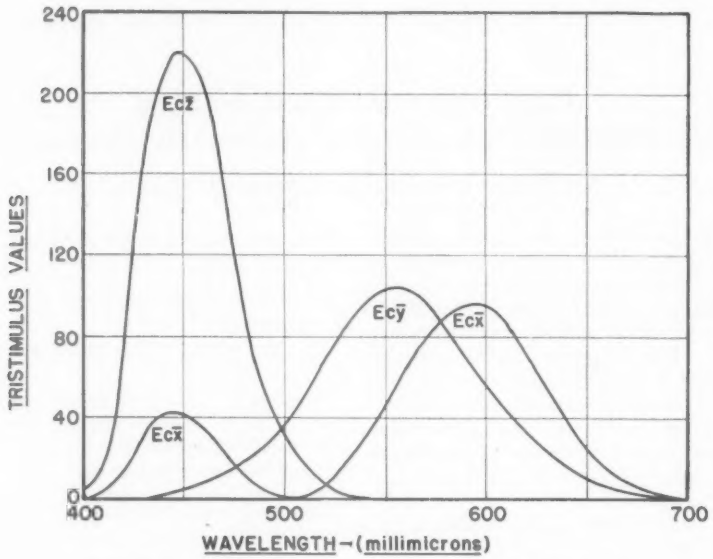

FIGURE 1.—Tristimulus values weighted with illuminant C for the visible wavelength range.

characteristics for the X primary filter are shown by the curves in Figure 4. Comparison with the corresponding curve in Figure 1 shows that the curve is divided into two sections (400 to 500 and 500 to 700 millimicrons). The data for each of these sections are relative for the specific section. The reason for this division is explained below. The relative light transmission curves

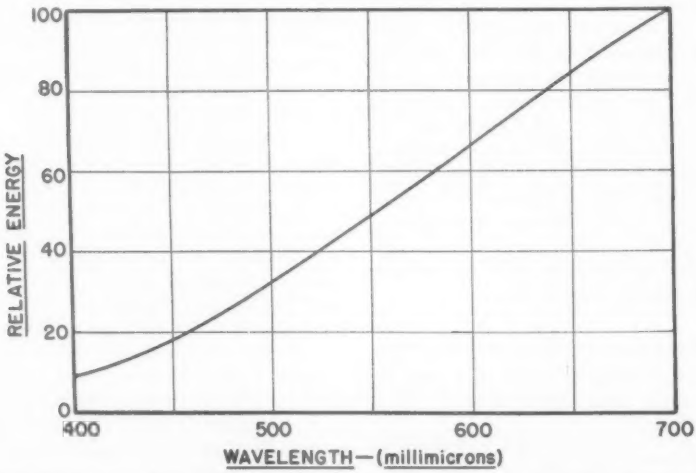

FIGURE 2.—Relative spectral energy distribution for filterphotometer light source.

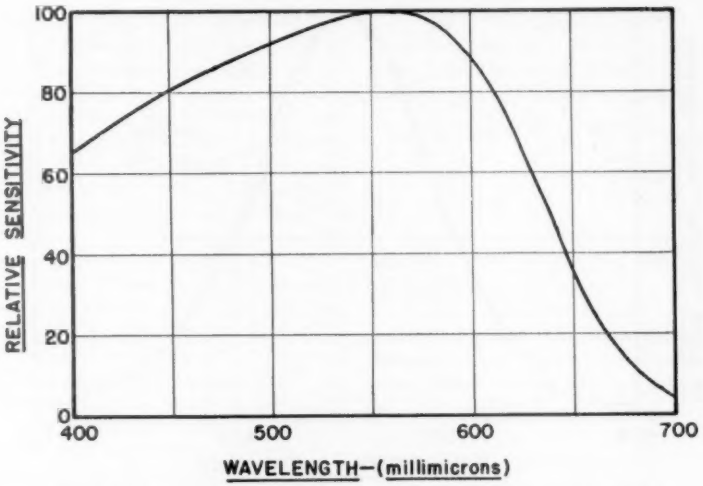

FIGURE 3.—Relative sensitivity for filterphotometer photoelectric cell.

for the Y and Z primary filters are shown, respectively, in Figure 5 and Figure 6.

The Corning Glass Works manufacture three tristimulus light filters having relative transmission characteristics similar to those calculated for the specifications. The relative transmission curve for Corning filter CS-3-107 is presented in Figure 4, where its shape is shown to be almost identical to that for the X primary specifications in the region from 500 to 700 millimicrons. Corning filter CS-5-70 has characteristics that are reasonably satisfactory for the 400 to 500 millimicron region of

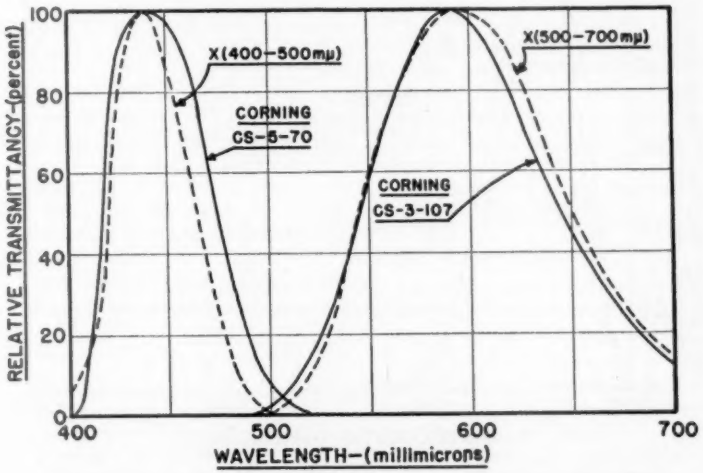

FIGURE 4.—Relative transmittancy data for specifications and corning tristimulus filters (X curves).

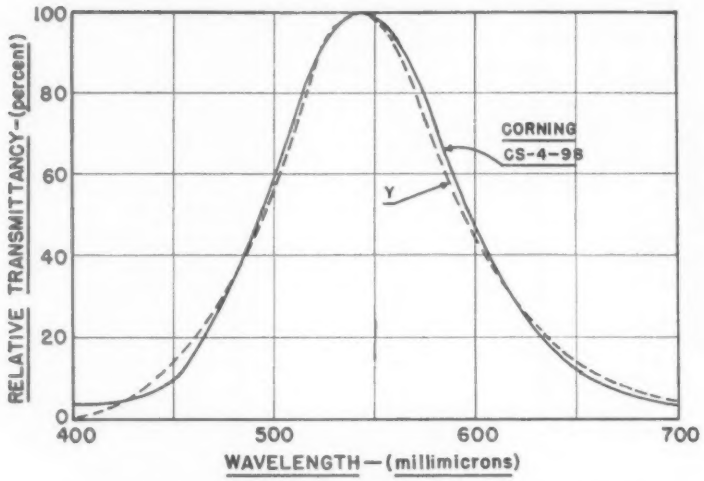

FIGURE 5.—Relative transmittancy data for specifications and corning tristimulus filter (*Y* curve).

the *X* primary specifications (Figure 4), and also for the *Z* primary specifications (Figure 6). The transmission characteristics for the *Y* primary are compared with the characteristics of Corning filter CS-4-98 in Figure 5, showing a very close similarity between the two curves.

The primary data for the color determination of industrial wastes are obtained as the percentage light transmission values for each of the three

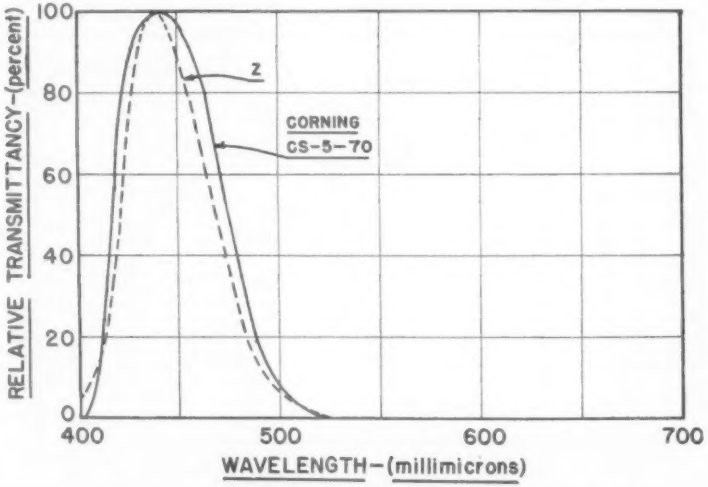

FIGURE 6.—Relative transmittancy data for specifications and corning tristimulus filter (*Z* curve).

tristimulus filters. The percentage of light transmission is determined on the basis of a distilled water blank, which is assumed to have a transmission value of 100 per cent. The percentage transmission value for the Y filter is recorded directly as the luminance. The tristimulus values for the X, Y, and Z filters are determined by multiplying the respective percentage transmission values by the corresponding total color contributions for each of the primaries. The latter values are determined from the relative areas under the $Ec\,\bar{x}$, $Ec\,\bar{y}$, and $Ec\,\bar{z}$ curves of Figure 1. The total color contribution factors for the X and Z transmission values were calculated to be, respectively, 0.316 and 0.374. As the contribution of the X primary is determined as the sum of two stages, the percentage transmission values obtained with the X and Z light filters are multiplied by the factors representing the areas under the respective sections of the $Ec\,\bar{x}$ curve (Figure 1). The X tristimulus value is the total of the contributions as determined with the X filter in the longer wavelength region and with the Z filter in the shorter wavelength region. The X primary color contribution factors were found to be 0.25 for the X filter transmission value and 0.06 for the Z filter transmission value.

Apparatus

a. Filterphotometer.—The filterphotometer used for this method shall have the type of light source, photoelectric cell, and tristimulus filters described below, using 10-mm. light absorption cells (Fisher Electrophotometer or equivalent).

b. Light source.—The filterphotometer light source shall be a tungsten lamp operating at a color temperature of 3,000° K. (G. E. lamp No. 1719 or equivalent).

c. Photoelectric cell.—The filterphotometer photoelectric cell shall have relative sensitivity characteristics similar to those of the G. E. photovoltaic cell, type PV-1.

d. Tristimulus filters.—The tristimulus filters shall have transmission characteristics similar to those for the following Corning Glass Works filters:

Visibility Function	Color Specification
X	CS-3-107
Y	CS-4-98
Z	CS-5-70

The Z filter shall be used to represent the $Ec\,\bar{z}$ primary and the blue section of the $Ec\,\bar{x}$ primary.

e. The remainder of the apparatus has been specified in the spectrophotometric method (2) and consists of glassware, filter crucibles, filter aid, and a vacuum system.

Procedure

Preparation of the Sample

Prior to determination of light transmission data, the temperature and pH of the wastes are adjusted, and the samples are clarified as described in the spectrophotometric method (2).

Light Transmission Characteristics

Thoroughly clean and rinse the 10-mm. absorption cells with distilled water. Rinse one of the absorption cells twice with the filtered waste and clean the external transmission surfaces with lens paper before making the waste transmission determinations. Use distilled water as the blank (100 per cent transmission) in another cell, and determine the percentage of light transmission through the waste for each of the three tristimulus light filters.

Color Characteristics

The luminance value is determined directly as the percentage transmission value obtained with the Y light filter. The tristimulus values are determined by multiplying the three tristimulus transmission values by the primary factors presented in Table I.

The trichromatic coefficients, dominant wavelength, and purity are determined and expressed in the same

TABLE I.—Primary Factors for Transmission Data

Light Filter Transmission Values (%)	Primary Factors	Tristimulus Values
X	0.06	X
Z	0.25	
Y	0.316	Y
Z	0.374	Z

manner as described for the spectrophotometric method (2).

Comparison of Color Classifications Results Obtained by Spectrophotometric and Filterphotometric Methods

The color characteristics of several industrial wastes were determined by spectrophotometric and filterphotometric methods for comparison. These data were obtained with both old (5 years) and new parts for the light source and photoelectric cells in the filterphotometer.

The color classification data determined by these methods are presented in Tables II and III. The filterphotometric data were determined with the illuminant intensity in position B, because this intensity gave the most accurate results.

The data show that the color classification results obtained by the spectrophotometric and filterphotometric methods are in fairly close agreement. The variation in the results is mainly due to the difference between the trans-

TABLE II.—Color Classification Results for Various Industrial Wastes as Determined by Spectrophotometric and Filterphotometric Methods

No.	Waste	Instrument[1]	Color Classification		
			Dominant Wavelength (mμ.)	Luminance (%)	Purity (%)
1	Blue dye	Spectrophotometer[2]	479	62.6	23
		Spectrophotometer[3]	479	63.0	23
		Filterphotometer[4]	479	63.3	24
2	Yellow dye	Spectrophotometer[2]	573	87.4	80
		Spectrophotometer[3]	573	87.0	80
		Filterphotometer[4]	573	89.4	78
3	Yeast (pH 6.3)	Spectrophotometer[2]	578	56.5	53
		Filterphotometer[4]	578	58.7	53
4	Yeast (dilute)	Spectrophotometer[2]	550	98.9	1
		Filterphotometer[4]	570	98.8	1
5	Sulphite cooking liquor (pH 4.0)	Spectrophotometer[3]	576	82.4	28
		Filterphotometer[4]	576	83.1	28
6	Sulphite cooking liquor (pH 8.0)	Spectrophotometer[3]	581	46.5	39
		Filterphotometer[4]	580	49.6	39
7	Slaughterhouse (pH 7.5)	Spectrophotometer[3]	580	60.9	37
		Filterphotometer[4]	584	62.4	35
8	Beet canning (pH 5.5)	Spectrophotometer[2]	506C	29.7	54
		Filterphotometer[4]	500C	34.9	45

[1] The filterphotometer used contained a light source and photoelectric cells which had been used in the laboratory for approximately 5 years.
[2] 10 selected ordinates.
[3] 30 selected ordinates.
[4] Lamp intensity B.

TABLE III.—Color Classification Results for Various Industrial Wastes as Determined by Spectrophotometric and Filterphotometric Methods

No.	Waste	Instrument[1]	Color Classification		
			Dominant Wavelength (mμ.)	Luminance (%)	Purity (%)
1	Blue dye	Spectrophotometer[2]	479	64.1	23
		Filterphotometer[3]	477	62.7	23
2	Yellow dye	Spectrophotometer[2]	573	87.8	80
		Filterphotometer[3]	572	90.8	79

[1] The filterphotometer used contained a new light source and new photoelectric cells.
[2] 10 selected ordinates.
[3] Lamp intensity B.

mission characteristics of the tristimulus light filters and the actual specifications for these filters.

Comparison of the results obtained with the old (Table II) and new (Table III) filterphotometer parts shows that the change in characteristics of the light source and photoelectric cells is not appreciable over a 5-year operational period.

Sample Calculations

The following sample calculations are presented for the blue dye waste No. 1 (Table II):

1. Transmission Data

Sample	Illuminant Intensity	Transmission (%)		
		CS-3-107	CS-4-98	CS-5-70
Blue dye	B	54.4	63.3	93.8

2. X Tristimulus Data (Corning filters CS-5-70 and CS-3-107)

The appropriate transmission values were multiplied by the respective primary factors (Table I).

X (400 to 500 mμ.) = 0.06(93.8) = 5.6
X (500 to 700 mμ.) = 0.25(54.4) = 13.6

Total X tristimulus value = 19.2

3. Y Tristimulus value (Corning filter CS-4-98) = 0.316 (63.3) = 20.0

4. Z Tristimulus value (Corning filter CS-5-70) = 0.374 (93.8) = 35.2

5. Trichromatic coefficients:

$$x = 19.2/74.4 = 0.258;$$
$$y = 20.0/74.4 = 0.269;$$

and

$$z = 35.2/74.4 = 0.473.$$

Summary

A simplified and less costly method, using tristimulus light filters combined with a specific light source and photoelectric cell, is presented for the filterphotometric determination of industrial waste color characteristics. The results obtained with this method are approximately the same as those obtained with a spectrophotometric method.

Acknowledgment

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References

1. Hardy, A. C., "Handbook of Colorimetry." Technology Press, Boston, Mass. (1936).
2. Rudolfs, W., and Hanlon, W. D., "Determination and Removal of Color in Industrial Wastes. I. Determination by Spectrophotometric Method." This Journal, 23, 9, 1125 (Sept., 1951).

Stream Pollution

EFFECT OF CYANIDE ON BIOCHEMICAL OXIDATION IN SEWAGE AND POLLUTED WATER

By F. J. Ludzack, W. Allan Moore, H. L. Krieger, and C. C. Ruchhoft

Chemists and Sanitary Engineer Director, respectively, U.S.P.H.S., Environmental Health Center, Cincinnati, Ohio

In a previous paper (4) data showing the effect of copper and hexavalent chromium on the biochemical oxygen demand (B.O.D.) of sewage dilutions were presented. Another ion which is a common constituent of certain industrial wastes is the cyanide radical. Its deleterious effect on stream fauna has long been known, but its effect on the self-purification of streams and sewage treatment has not been extensively studied. Lockett and Griffiths (2) found that 5.0 p.p.m. of cyanide in sewage treated by the activated sludge process had a marked inhibitory effect on the purification process. Sawyer and Hermann (7) studied the effect of cyanide on the B.O.D. of a synthetic sewage consisting of a mixture of glucose and peptone in "Standard Methods" (8) phosphate dilution water and also in a mineral and nitrogen supplemented bicarbonate water (1). The present study was confined to the effect of cyanide on the B.O.D. of domestic sewage and river waters.

Procedure

In studying the effect of various concentrations of cyanide on the B.O.D. of domestic sewage and river waters, 10-day series were set up and the B.O.D. determined daily. All of these series were set up in duplicate, together with a control containing no cyanide. Studies on the following four types of series were completed:

1. Sewage in "Standard Methods" phosphate dilution water without ammonium sulfate.
2. Ohio River water with some fresh sewage added to raise its oxygen demand.
3. Sewage in bicarbonate dilution water.
4. Great Miami River water collected at Franklin, Ohio.

The sewage used was fresh domestic sewage, containing no industrial wastes, obtained at the Cincinnati Environmental Health Center laboratory. On preliminary studies with this sewage, the effect of cyanide in concentrations of 0.01, 0.05, 0.1, 0.2, 0.3, 0.5, 0.8, 1.0, 1.5, 2.0, 3.0, 6.0, 12.0, 25.0, and 50.0 p.p.m. was checked. Concentrations of 0.01 and 0.05 p.p.m. showed no inhibitory effect on the B.O.D. of sewage. It was necessary to reach a concentration of 0.3 to 0.5 p.p.m. before the 5-day B.O.D. inhibition was appreciable. It is true that 0.1 p.p.m. of cyanide has been found to be toxic to certain fish life. However, this study was concerned with its effect on biochemical oxidation and not on a specific biological species. The results, excluding those for 0.01 and 0.05 p.p.m. of cyanide, are shown in Table I. Following these studies, concentrations of 0.5, 1.0, 2.0, 3.0, 6.0, and 12.0 p.p.m. and a control were used to establish the pattern of behavior.

TABLE I.—Percentage of B.O.D. Recovered with Cyanide-Dosed Samples of Domestic Sewage in Phosphate Dilution Water

CN (p.p.m.)	Days									
	1	2	3	4	5	6	7	8	9	10
0.1	93.7	95.0	95.8	99.0	95.7	96.0	98.0	97.9	100.3	99.1
0.2	95.0	92.4	98.8	96.0	95.0	98.1	95.0	97.8	94.2	95.7
0.3	88.4	90.2	88.7	88.7	92.4	89.5	90.2	96.0	90.7	92.7
0.5	84.4	83.7	80.5	76.2	83.3	83.4	89.1	90.2	87.5	86.9
0.8	50.6	65.5	73.5	68.3	72.1	72.3	80.3	82.8	77.7	82.9
1.0	55.8	74.8	73.3	68.7	73.3	72.6	76.4	81.5	78.5	78.2
1.5	31.8	74.0	71.4	67.4	69.8	68.5	69.5	79.5	71.5	80.3
2.0	45.0	64.7	65.3	62.5	67.3	67.9	72.7	71.0	70.3	71.3
3.0	35.9	41.6	53.3	56.6	62.7	64.0	66.9	70.2	67.3	69.3
6.0	47.6	39.3	36.0	38.6	50.5	48.7	56.6	63.7	56.7	58.4
12.0	49.2	39.9	32.0	27.6	30.6	30.3	33.7	42.0	44.6	46.2
25.0	5.8	0	3.2	5.2	3.8	3.5	4.1	6.7	6.6	14.3
50.0	Less than 1.0 per cent recovery									

Several B.O.D. series were analyzed for cyanide content on the initial day and rechecked at intervals throughout the 10-day period to follow the changes in cyanide concentration during incubation. A modified Liebig titration using 0.001 N $AgNO_3$ and the Rhodanine (6) internal indicator were used to determine the cyanide level. It was found that cyanate had no effect on this titration.

Results

With the various concentrations of cyanide in the different waters the lowest level to have at least a 5 per cent inhibitory effect over the 10-day period of observation was 0.3 p.p.m. in the two synthetic dilution waters and in the Ohio River water. The Great Miami River water had a 5 per cent inhibition of B.O.D. with 0.2 p.p.m. CN. In order to obtain a more significant difference in rate of oxygen utilization, a 0.5-p.p.m. concentration of CN was the lowest used for the majority of the test series. When the cyanide concentration was 25 p.p.m. in fresh sewage with phosphate dilution water, the sample required 15 to 20 days to deoxygenate to the value of the 1-day B.O.D. of the control. As this was too long for any practical B.O.D. series, a 12-p.p.m. CN concentration was accepted as the highest to be used for the comparative tests. The 50-p.p.m. cyanide concentrations in a similar system indicated very little deoxygenation in 60-day incubation, even when the sample was reseeded after 50 days.

Effects of cyanide on the B.O.D. of domestic sewage in phosphate dilution water are shown in Figure 1, which includes the data from eight series in duplicate. The average B.O.D. values indicate a fairly even spread of increasing inhibition as the cyanide concentration is increased. With concentrations up to 3 p.p.m. of cyanide, good agreement was obtainable from one series to another. The maximum variation obtained was 9 per cent of the control B.O.D. on different series of the same cyanide concentration. Above 3.0 p.p.m. of cyanide the B.O.D. results were quite erratic. This apparently was due to the varied toxic effect on different seeds, as well as other contributing factors. At about 3 p.p.m., a definite lag period changes the shape of the B.O.D. curve from the normal. The lag increases in duration as the cyanide concentration is increased. The time, in days, required for cyanide-dosed samples to attain the 1-day B.O.D. of the control was used as one parameter of the effect of cyanide. In phosphate

dilution water samples containing up to 2 p.p.m. CN reached the level of the 1-day control in approximately two days. Samples containing higher cyanide levels showed increased lags. Seven and one-half days were required before the sample with 12 p.p.m. of cyanide reached the 1-day B.O.D. of the control.

Daily nitrogen analyses for ammonia, nitrite, and nitrate were made on three series at the beginning of this study, but since little change was observed, the nitrogen analyses were omitted except for occasional checks. The mean results, however, do show a slight nitrification on the control samples, but none on any of the cyanide-dosed samples. This is in line with the findings of Ridenour and Greenbank (5). These workers did not find a complete inhibition of nitrification, but rather that it was greatly retarded. In this connection, it must be remembered that in these studies the authors were working with sludges that had been acclimated to the various compounds added and thus their effect on nitrification might not be so pronounced as in the present studies.

Figure 2 shows the average B.O.D. data on three series in duplicate with domestic sewage in bicarbonate dilution water. In this case, the initial inhibition of B.O.D. was more pronounced, but the time required to reach the 1-day B.O.D. level of the control was less for cyanide concentrations above 2 p.p.m. than those in phosphate dilution water. Another significant difference is the pronounced similarity of the B.O.D. curves for cyanide concentrations from 0.5 to 6.0 p.p.m. after the end of the fifth day of incubation.

In Figure 3 are plotted the results of five series in Ohio River water obtained at Cincinnati. The B.O.D.'s of this water containing concentrations of cyanide from 0.5 to 6.0 p.p.m. were more similar than they were in bicar-

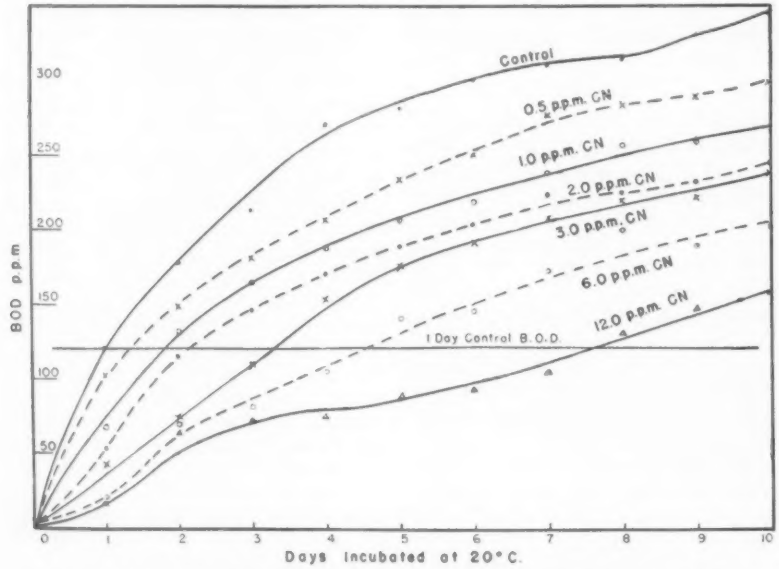

FIGURE 1.—Effect of cyanide on B.O.D. of domestic sewage in phosphate dilution water.

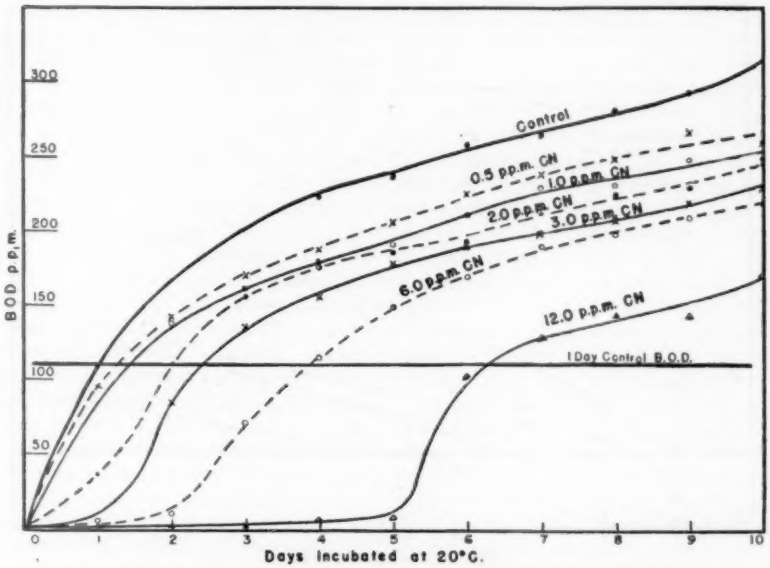

FIGURE 2.—Effect of cyanide on B.O.D. of domestic sewage in bicarbonate dilution water.

bonate dilution water, with a proportionally greater inhibition shown by small concentrations of cyanide.

By the end of five days of incubation and thereafter the B.O.D. of the samples having 6 p.p.m. of cyanide was slightly above that containing 2 p.p.m. Definite lag periods in the B.O.D. were found for 3 or more p.p.m. of cyanide, but the time to reach the 1-day control B.O.D. value was longer for the lower cyanide levels and shorter for higher cyanide levels than for the corresponding concentrations in the synthetic dilution waters.

Figure 4 gives the results of the effect of various cyanide concentrations on the B.O.D. of Great Miami River water obtained at Franklin, Ohio. This point of sampling was selected because there are known sources of cyanide waste in the stream about 15 mi. upstream from this point. These curves again show a marked decrease in the time required for reaching the level of the 1-day control B.O.D. In this water the 12 p.p.m. CN reaches this stage in 3.5 days, as compared to 7.5 days in the phosphate dilution water. Here, the 6-p.p.m. CN samples reached the B.O.D. level of the lower dosages of CN at the end of the fourth day, and by the tenth day showed a definitely higher B.O.D. The B.O.D. of the sample containing 12 p.p.m. of CN by the eighth day was higher than all the others, except for that containing 6 p.p.m. A slight tendency toward this same effect was noted in Ohio River water. The greater B.O.D. of the samples having higher cyanide concentrations was associated with a much greater loss in cyanide during the incubation period, as discussed later herein.

When the lag periods were first noted in the B.O.D. curves, an attempt was made to correlate the termi-

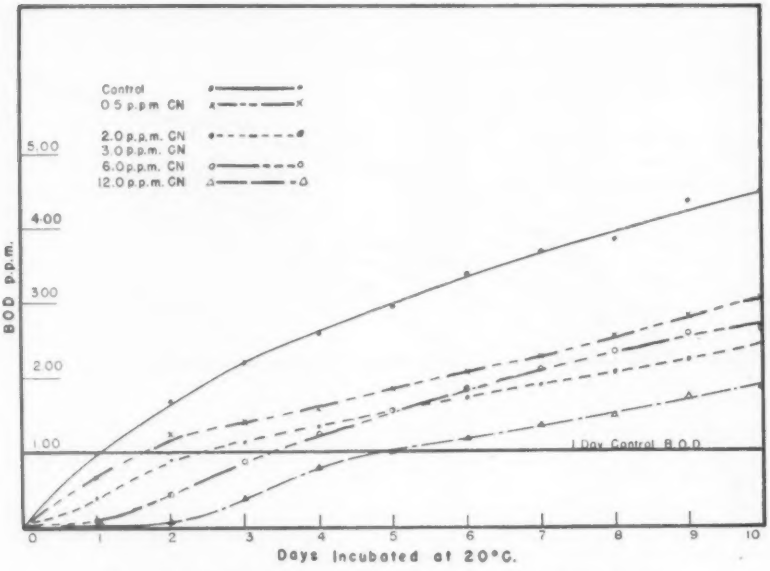

FIGURE 3.—Effect of cyanide on B.O.D. of Ohio River water.

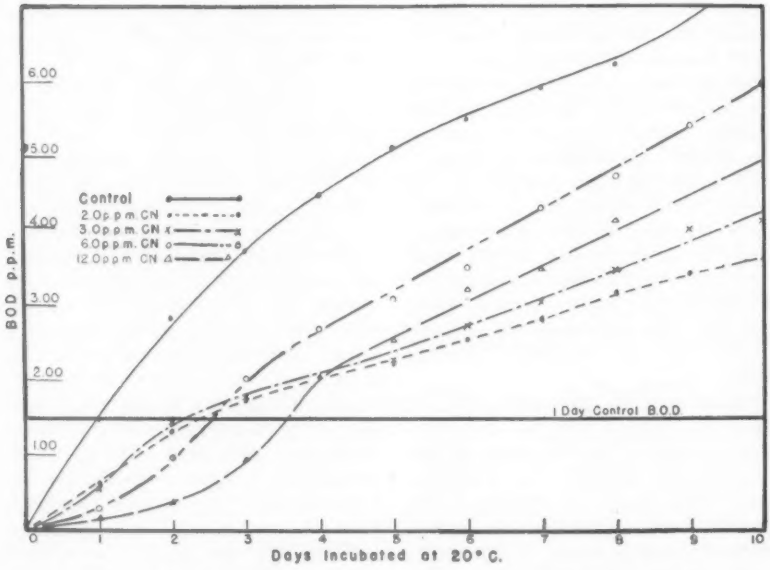

FIGURE 4.—Effect of cyanide on B.O.D. of Big Miami River water.

nation of this lag period with the disappearance of the cyanide radical. Accordingly, CN determinations of several series including the four types of waters were made on the initial day and at varying intervals throughout the 10-day period. Figure 5 indicates the cyanide loss in the Ohio River water and includes data on three different series. These data are also representative for both of the synthetic dilution waters, which followed essentially the same pattern. Loss of cyanide was about 50 per cent in 10 days for the 0.5-p.p.m. concentration, approximately 25 per cent loss from 1 p.p.m. to 6 p.p.m., and less than 10 per cent loss at 12 p.p.m. Therefore, it is apparent that the microorganisms present are capable of initiating biochemical oxidation in the sample long before the cyanide has disappeared. The lag period may represent the time required to permit a specialized microbic type or types to increase in numbers to the point where their effects are detectable in the B.O.D. test.

Figure 6 indicates the results obtained in the two series of Great Miami River water on cyanide persistence. As expected, the behavior on the persistence of cyanide is as radically different from that of the other waters tested as is the case with the B.O.D. curves. Here again, self-purification was noticeable before the cyanide disappeared. Apparently larger numbers of flora and fauna are already present in the river which are capable of more rapid biochemical oxidation in the presence of cyanide than is the case in the other waters studied.

In the Great Miami River water a concentration of 6.0 p.p.m. of cyanide showed the highest rate of cyanide removal. The removal, however, at other levels was not so pronounced. In the Ohio River water the 6-p.p.m. concentration was much more erratic in behavior than any of the other concentrations used. However, it did not show as great a removal as was found for the Great Miami River water. The slopes of the curves for cyanide

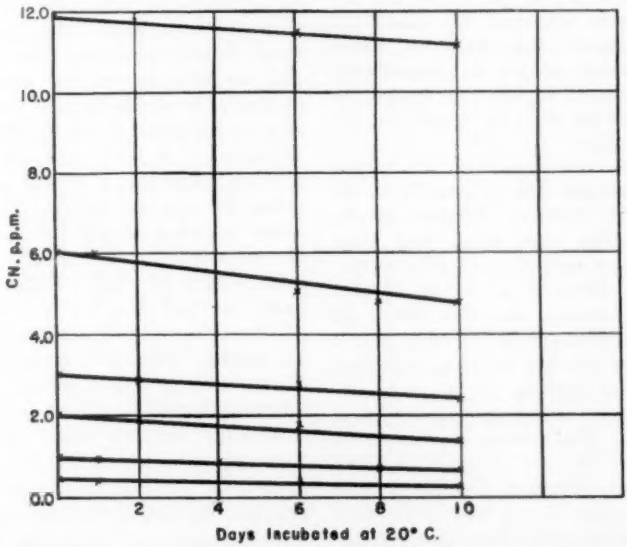

FIGURE 5.—Cyanide persistence in B.O.D. bottles using Ohio River water.

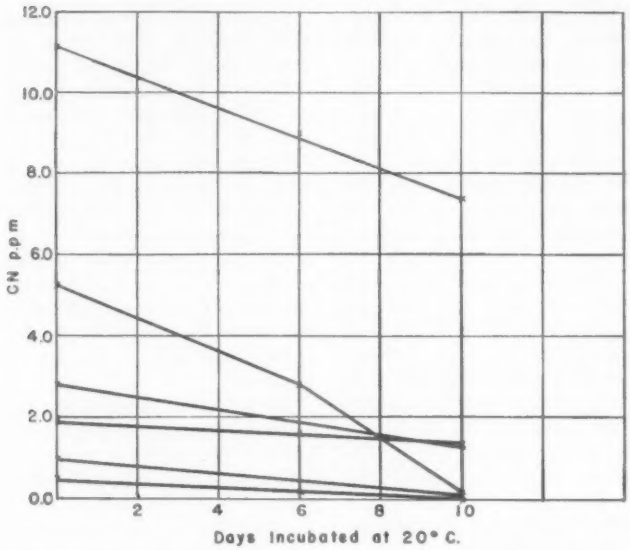

FIGURE 6.—Cyanide persistence in B.O.D. bottles using Big Miami River water.

disappearance in the Ohio River water are noticeably different from those of the Great Miami River water. In the Ohio River water the slopes are approximately the same for most concentrations, whereas the Great Miami River water shows an appreciably higher loss at higher CN levels. In both cases the 6-p.p.m. sample has the greatest slope.

Because the closed B.O.D. bottles would preclude loss of cyanide to the atmosphere through diffusion effects, three bottles were filled with Ohio River water and plugged with cotton. One was stored in the 20° C. incubator in darkness, one was stored at room temperature in the light and a third was aerated at room temperature. The cyanide content was determined on each bottle at irregular intervals. The results are shown in Figure 7. The loss of cyanide in that case where diffusion is a factor was approximately 35 per cent in the first 6 days, as compared with about 12 per cent in the B.O.D. bottles in the same period. Aeration resulted in loss of about 83 per cent in 18 hr. The water in this case was at pH 7.4. An aeration experiment was made on Great Miami River water at pH 8.2 and the cyanide residual determined at hourly intervals for the first 8 hr. and at irregular intervals thereafter (Figure 8). In 24 hr. at pH 8.2, with aeration there was a 40 per cent decrease in cyanide, whereas the same water adjusted to pH 7.4 showed a 69 per cent loss in cyanide in the same length of time. Buffering capacity and pH thus have a significant effect on removal of cyanide by physical means. Milne (3), from a study of equilibrium conditions in cyanide solutions, found that with aeration a continuous loss of HCN occurred. This loss was compensated for by the hydrolysis of cyanide in order to maintain the cyanide-hydrocyanic acid equilibrium.

Determination of Cyanide

To check the reliability of the cyanide determination, a series of 10 replicate runs was made on Great Miami River water with each of two concentrations of added cyanide. The two cyanide levels used were 0.4 and 1.4 p.p.m., with a blank subtracted in each case as determined by titrating the river water without added cyanide. These concentrations were checked because of the difficulty experienced in determining CN in concentrations below 1 p.p.m. The range of titration volume was 0.7 ml. on a mean of 1.44 ml. at the lower level. The standard deviation was $\pm$ 0.23 ml. on this titration. Cyanide level as determined on the mean titration was 0.37 ± 0.06 p.p.m. At the higher level of cyanide the range of titrations was 0.3 ml. on a mean of 5.51 ml. The standard deviation of the titration was $\pm$ 0.16 ml. The cyanide content according to the mean was 1.43 ± 0.04 p.p.m. Pearson's coefficient of variation was 0.162 for the smaller and 0.028 for the larger of the two titrations.

The cyanide test is dependent upon the experience of the analyst in recognizing the end point, as the color change is relatively slight. However, with experience and a reference standard to facilitate judgment, reproducible results can be obtained on relatively clear samples.

Removal of Cyanide

A method of removing cyanide without seriously affecting B.O.D. results is desirable. Several methods that are known to decrease the cyanide level were tried, but either the cyanide was not reduced to a sufficient level or the B.O.D. results were erratic. Various modifications of aeration were tried with and without heating or acidification, but the cyanide was not reduced more than about 40 per cent in 3 hr. when 6 p.p.m. cyanide were present. A vacuum combined with agitation also was ineffectual. Adding

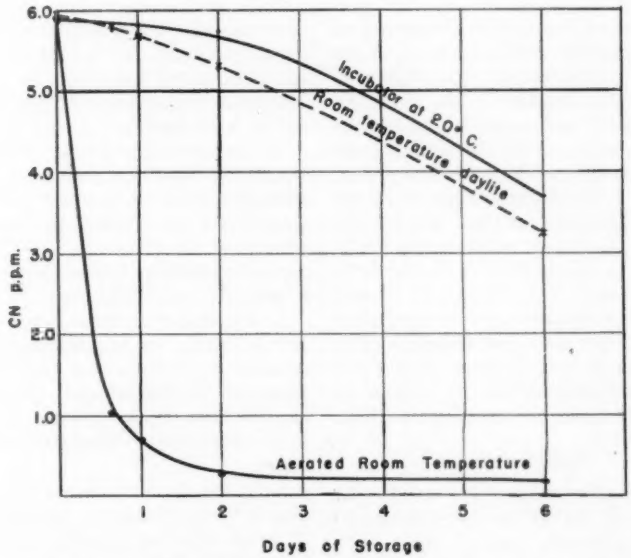

FIGURE 7.—Cyanide persistence in open bottles of Ohio River water.

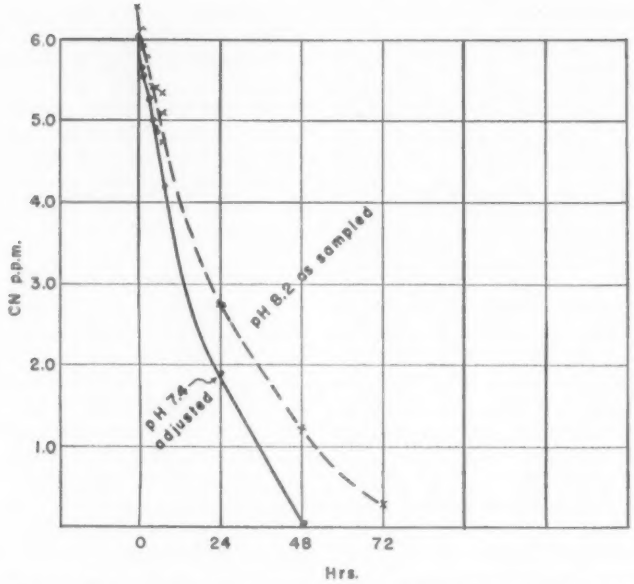

FIGURE 8.—Cyanide persistence in aerated Big Miami River water.

a measured amount of silver salt for the purpose of complexing the cyanide present resulted in formation of silver chlorides with little effect on cyanide. Acidification with H_2SO_4 to pH 2.0 plus heating to about 95° C. for 30 min. and aeration during the whole process resulted in consistent reduction of cyanide to levels between 0.3 and 1 p.p.m. regardless of initial cyanide content, but the resultant hydrolysis of organic solids made it impossible to check B.O.D. results with the untreated control. About 50 per cent of the samples showed agreement within 20 per cent, but the remainder were high or low, as much as 100 per cent. The effect of the hydrolysis on the B.O.D. limits the use of the method.

Conclusions

1. The effect of cyanide on the inhibition of B.O.D. is quite variable, depending on the type of water, specialized seed developed, and other factors.

2. Specialized microbic growths are able to effect self-purification and oxidize organic matter in the presence of cyanide after an initial lag period of a duration depending on cyanide content and the stage of development of the seed organisms.

3. Under conditions of the B.O.D. test, little loss of cyanide is accomplished during the normal incubation period of 5 days, except in water samples in which there is a previous history of cyanide pollution and in which a suitable flora is already developed.

4. The loss of cyanide from volatilization during stream self-purification is more rapid than that produced by chemical or biochemical destruction, except when a specialized flora has been previously developed in the water.

5. In the river waters studied, there was a proportionately greater effect of small doses of cyanide on the inhibition of B.O.D. Higher cyanide concentrations showed relatively small

additional increments of inhibitions as long as the cyanide content was not appreciably greater than 6 p.p.m.

6. In all of the waters studied, cyanide concentrations up to 6 p.p.m. were purified as much as 50 per cent or more of the control within the 10 days of incubation.

References

1. Lea, W. L., and Nichols, M. S., "Influence of Phosphorus and Nitrogen on Biochemical Oxygen Demand." *Sewage Works Jour.*, **9**, 1, 34 (Jan., 1937).
2. Lockett, W. T., and Griffiths, J., "Cyanides in Trade Effluents and Their Effect on the Bacterial Purification of Sewage." *Jour. and Proc.*, Inst. Sew. Purif., Part 2, p. 121 (1947).
3. Milne, D., "Equilibria in Dilute Cyanide Waste Solutions." THIS JOURNAL, **22**, 7, 904 (July, 1950).
4. Placak, O. R., Ruchhoft, C. C., and Snapp, R. G. *Ind. Eng. Chem.*, **41**, 2238 (1949).
5. Ridenour, G. M., and Greenbank, J., "Preliminary Report on Effect of Cyanide Case Hardening, Copper and Zinc Plating Waste on Activated Sludge Sewage Treatment." *Sewage Works Jour.*, **16**, 4, 774 (July, 1944).
6. Ryan, J. A., and Culshaw, G. W. *Analyst*, **69**, 370 (1944).
7. Sawyer, C. N., and Hermann, E. R. Paper presented at 116th Meeting, Am. Chem. Soc., Atlantic City, N. J. (Sept., 1949).
8. "Standard Methods for the Examination of Water and Sewage." 9th Edition, p. 140, Am. Pub. Health Assn. (1946).

NEW HAMPSHIRE JOINS NEW ENGLAND COMPACT

On July 30, 1951, Governor Sherman Adams of New Hampshire, signed a bill providing for the ratification of the New England Interstate Water Pollution Control Commission Compact by the New Hampshire Water Pollution Commission on behalf of the state. Immediately following the signing of the bill, the New Hampshire Water Pollution Commission met and executed the Compact. The Commissioners to represent New Hampshire will now be appointed by the Governor.

With the ratification of the Compact by New Hampshire, the Commission now includes six of the seven eligible states; namely, Massachusetts, Connecticut, Rhode Island, New York, Vermont, and New Hampshire.

ELECTRONIC PRECIPITATING AND DRYING DEVICE FOR WATER-SUSPENDED MATTER

By Theodore A. Olson, Alton H. Hollenbeck, and Colleen A. Brady

Associate Professor, Junior Scientist, and Laboratory Technologist, respectively, School of Public Health, University of Minnesota, Minneapolis, Minn.

In the course of studies being carried on to ascertain the nature of the toxic agent or agents involved in blue-green algae poisoning episodes, it became apparent that a finely divided dry algal powder which had not been dehydrated at an unduly high temperature would be a desirable raw product for certain extraction procedures. Various types of available dryers, including both high and low temperature devices, were investigated, but none was found adaptable. It was necessary, therefore, to design a dryer suited to the specific needs of the studies.

Previous experiments had indicated that when an algal suspension was sprayed against a hot aluminum plate, a fine air-borne powder comparable to an aerosol was produced. The drying took place almost instantaneously, for after the original impact, the reflected mist was visible only 3 to 4 in. from the plate. Within the mist area the temperature was low, as evidenced by coolness to the hand. Although this experiment had been carried on in a chemical hood equipped with a strong exhaust blower, the air-borne particles spread quickly throughout the entire laboratory. The next problem, therefore, involved the removal of the particles from the air; electronic precipitation seemed a practical solution. As a result, a dryer was designed and constructed incorporating these methods of evaporation and precipitation.

Makeup of Unit

The unit as finally constructed is essentially a rectangular plywood box reinforced by an angle-iron frame. The over-all dimensions are 16½ in. by 40 in. by 66 in. (see Figure 1). A standard air-line sprayer unit of the type used by painters is employed to produce the algal mist. This spray gun, operating at a pressure of 25 to 40 p.s.i. and consuming 2 to 4 cu. ft. of air per second, is a nonfouling, syphon feed type equipped with a round spray head. The sprayer is fixed at the inlet of an evaporator consisting of a 42-in. black iron tee 9 in. in diameter, heated by 8 Bunsen burners, and closed at its far end by an aluminum plate. Two 90° elbows and one 18-in. straight section constitute the remainder of the intake tube. A squirrel-cage blower driven by a ⅙-hp. motor located on the lowermost level draws air through the dryer at the rate of 200 to 300 cu. ft. per minute. The algae particles are thus drawn past the ionizing wires and the collector plates of two precipitating units placed on successive levels. Each unit is 8 in. by 12 in. by 21½ in. and consists of 9 grounded and 8 charged collector plates preceded by 4 ionizing wires. The electrical charge is derived from a power pack capable of transforming and rectifying standard 115-v. a.c. to 10,000-v. d.c. This pack can, if necessary, operate up to 50 precipitator units of the 12-in. size.

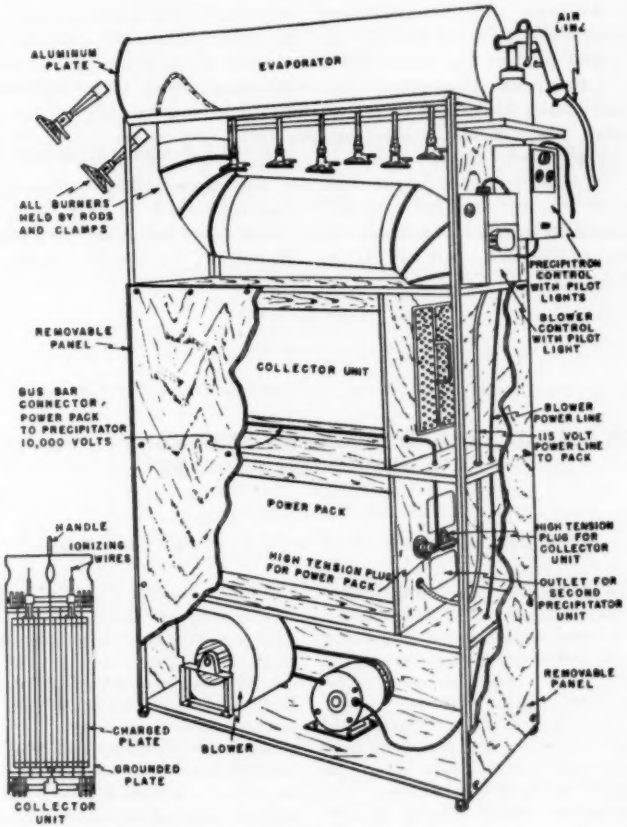

FIGURE 1.—Cutaway sketch of precipitron dryer.

The precipitator units and power pack used were purchased from the Air-Maze Corporation, Cleveland, Ohio.

Use of Unit

The device has proved successful for drying water suspensions of algae. Before drying, however, it is necessary to strain the algae suspensions through a coarse sieve to remove leaf fragments, shells of mollusks, twigs, and other debris. To further reduce the possibility of clogging the spray nozzle, the material is processed in a Waring blender to break up any remaining clumps of algae.

When a properly prepared algal suspension is sprayed into the evaporator and the rate of airflow is 225 cu. ft. per minute, algae particles are completely precipitated by the units. The algal powder is soft and talc-like and has a particle size varying from 1.2 to 24 microns, with the greatest number between 1.5 and 10 microns. The moisture content of the dryed material immediately after recovery from the collector plates is 7 per cent.

Before spraying algae into the dryer, the evaporator is preheated until the temperature of the exhaust

remains constant. The temperatures which have been recorded are 82° C. at the hottest part of the intake tube, 43° C. at the point of entry to the first precipitating unit, and 43° C. at the exhaust. As soon as the algal suspension is sprayed into the evaporator, the temperature in the intake tube drops to 68° C., but does not vary appreciably from previous readings at the entry to the first unit or at the exhaust. This indicates that particles of water-suspended natural products moving through the heated area at the aforementioned rate are not excessively heated by this drying method.

Acknowledgments

The investigation reported herein was supported in part by a research grant from the National Institutes of Health, U. S. Public Health Service.

NOTE ON TOLERANCE OF GREEN FLAGELLATE PROTOZOA TO HYDROGEN SULFIDE

By W. E. Abbott

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Samples of settled combined sewage have been placed in full stoppered bottles near a window on many occasions and kept under observation. Sooner or later the bottle contents have always turned green. In the meantime, the liquid obviously passes through septic stages. It is probable that in all these cases the green organisms have had to pass some stage of their growth in some degree of hydrogen sulfide. The green organisms which develop in the warmer months are small and resemble *Chlorella* under the microscope. *Euglena, Chlamydomonas,* and other large flagellate protozoa appear spontaneously in the winter.

A bottle was filled with settled sewage on December 14, 1950, and placed at the north window of a room maintained at about 12° C. Nothing much happened till January 23, 1951, when a green growth suddenly developed. By January 29 it was prominent. On removing the stopper the smell of hydrogen sulfide was very strong. The total sulfides were determined by the A.P.H.A. titration method and found equivalent to 11.1 p.p.m. S. The B.O.D. had declined from an initial figure of 262 to 183 p.p.m.

A most striking feature was that the green organisms in the daytime formed two bands down the side of the bottle. One was at the point nearest the light and the other directly opposite. Under the microscope they appeared as large motile flagellate protozoa resembling *Chlamydomonas.* Light preferences have also been observed in the winter whenever the Nottingham irrigation area effluents contained *Euglena* or *Chlamydomonas.* Sometimes all sought the light, sometimes all avoided it and frequently some of an apparently pure culture avoided the light while others strove to get as near its source as they could. In some of the latter type of behaviour the bottle has been stirred to disperse the organisms uniformly and then replaced. The original pattern is usually reproduced within an hour. In the case of partly filled sample bottles containing *Euglena* it was usual to find them nearly all at the surface nearest the light in the morning.

The light to which the bottle under discussion was exposed was very faint (of the order of 400 foot-candle-hours per day). It was amazing that such organisms could grow in such a medium and in such a faint light stimulus. It is credible that they could produce enough oxygen for their purposes in the hours of daylight, but no suggestion can be made as to how they existed during the nightly 18 hr. of darkness.

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SEWAGE WORKS ASPECTS OF RADIOLOGICAL PROBLEMS *

BY LEROY W. VAN KLEECK

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In the sewage works field, radiation will be both a peacetime and a wartime problem. New sources of radiation are here to stay, and man having now produced radioactive substances must learn to live with them. In the brief discussion which follows, the minimum theory needed for an understanding of radiology is presented.

Basic Theory

Atoms

An atom, which is the smallest particle of an element capable of entering into a chemical reaction, is composed of a positively charged nucleus surrounded by a negatively charged electron cloud. The fundamental particles in the nucleus are positively charged protons and neutrons, the latter having almost the same mass as protons but no electrical charge. The electron cloud surrounding the nucleus consists of negatively charged electrons of very small mass which are exactly equal in number to the protons in the atom's nucleus. Thus the atom has a neutral charge. The atomic number of an element indicates either the number of protons or electrons in each atom of that element. The mass number of an element, however, is the sum of the protons and neutrons in the nucleus of its atoms.

Isotopes

An isotope, which may occur naturally in nature or be artifically produced by man, is one of two or more forms of an element. At the present time, the 98 elements are known to have a total of 1,067 isotopes, of which 783, mostly man-made, are radioactive. All the isotopes of a particular element have the same atomic number, but different mass numbers. A radioactive isotope, or radioisotope, is simply an isotope whose atoms have unstable nuclei, which are undergoing spontaneous disintegration and change in an effort to attain stability.

The disintegration or decay of an unstable isotope proceeds at a characteristic rate for each radioisotope and cannot be changed by any available means. The rate of decay is known as the half-life and is the time required for a radioactive substance to lose 50 per cent of its activity. This disintegration process results in the formation of new nuclei; energy is liberated, accompanied by the emission of one or more types of radiation.

* Presented at 1951 Joint Meeting, New York Sewage and Industrial Wastes Association and New England Sewage Works Association; Springfield, Mass.; June 7–8, 1951.

All isotopes of an element, whether stable or unstable, are identical in chemical behavior, as it is only the outer electrons of atoms that enter into chemical reactions.

Radiations

Briefly, the types of radiation given off by the nuclei of atoms are as follows:

1. Alpha particles. These particles damage mostly internally. They travel but a few inches in air and are stopped by as slight a barrier as a piece of paper or the outer layer of human skin.

2. Beta particles. These particles travel about 10 ft. in air and may penetrate as much as one-third of an inch of tissue. Protection may be afforded by relatively thin sheets of plastic, glass, aluminum, or other materials. They are again primarily an internal hazard to humans.

3. Gamma rays. These rays, like X-rays, will pass through the human body and other objects. They are electromagnetic waves like radio waves or light waves. Light waves are visible to humans, whereas radio waves are not. Gamma rays, like radio waves, cannot be seen or felt by humans. They travel thousands of feet, and are therefore a serious external hazard. The "roentgen" is a unit of measure of gamma rays.

4. Neutron particles. These particles have no electrical charge and are very penetrating. Their range is more limited, however, than gamma rays. Neutrons constitute a serious external hazard to humans and also cause induced radioactivity in materials they strike.

Body damage by radiation is caused by cell ionization, whether the type of radiation is by external or internal means. The damage from external radiation is immediate, although the evidence may be delayed for long periods of time. Internal radiation is insidious. When radioactive material is fixed in the tissue, it is often excreted very slowly and so remains a long-term source of radiation bombardment within the individual. There is no known process to destroy or neutralize the radiation source, and methods to speed the excretion or shield the fixed material are unsatisfactory. The particular radioactive material, the part of the body it seeks, and its so-called biological half-life determine whether body elimination will be faster than absorption and hence the amount of body damage that will result.

Nuclear Fission

Nuclear fission results from the bombarding of atom nuclei with neutrons, with the formation of two or more lighter elements and the release of neutrons and energy. The process is similar to that of a toy balloon when the addition of one small increment of air causes it to burst. Likewise, atomic nuclei overstuffed with nuclear particles burst when one neutron is added by bombardment. In the atomic bomb when two sub-critical masses of uranium 235 or plutonium 239, either of which contains many neutrons, are brought quickly together to form an over-critical mass, neutrons split atoms in a chain reaction with the release of over 400 fission products, many of which are radioactive isotopes.

Sources of Radiation

X-rays in Medicine

X-ray machines in medicine have been a source of radiation for many years, but because of the localized area of the body exposed, the tissue damage is limited and recovery is relatively rapid.

X-rays in Industry

X-ray machines are used in industry for examining packages, castings, and employees themselves. Any careless-

ness in their use is attended by obvious hazard to humans, either through direct exposure or exposure to secondary rays.

Uranium and Radium

Uranium and radium, which are naturally radioactive materials, are used in medicine, in industrial processes, and in many everyday products such as static electricity eliminators, yellow Fiesta ware, spark plugs, green and pink sun glasses, yellow caution lights, luminous dials, and even false teeth. In most cases the principal hazards from this source is the unsafe handling of the uranium or radium.

Uranium Piles and Particle Accelerators

Chain reacting uranium piles, cyclotrons, betatrons, and other particle accelerator installations are the sources of radioisotopes, and of uranium 235 and plutonium 239. Such installations are either owned by the U. S. Atomic Energy Commission or private research laboratories, who are fully cognizant of the inherent dangers in their operation, and who take precautions by adequate shielding, and monitoring of operating personnel. Radioactivity from uranium piles is of concern to the public with respect to the disposal of waste cooling water or air, but here again the AEC has set up an elaborate system of controls.

Radioisotopes

Radioisotopes are finding increasing use in medicine, industry, research, and agriculture. Although most radioisotopes are distributed by the AEC, there are other sources over which they have no control. There is likewise no control by the AEC over radium. Obviously, as isotope uses expand there will be need to delegate control powers to other agencies. Public Health departments, for one, will do well to prepare for this duty in the years immediately ahead.

The AEC requires that the applicant for the receipt of radioisotopes assume the following responsibilities:

1. Assume liability for injury incurred in handling or using radioisotopes in his possession.
2. Use the material only for purposes authorized by the AEC.
3. Comply with all established government safety regulations.
4. Permit inspection of his facilities.
5. Keep records showing possession and disposal of radiomaterials.
6. Have a staff member trained in using radiomaterials.
7. Have adequate health physics facilities and equipment.
8. Publish results of investigations.

As of late fall, 1950, the AEC had made about 16,000 shipments of radioisotopes, of which nearly two-thirds were either I^{131} or P^{32}, both being relatively short-lived. The largest users have been those in medical therapy practice. Of the isotopes shipped, 90 per cent have had a half-life of less than 30 days, which makes consumer disposal of the waste product relatively easy. Long half-life isotopes present a more serious disposal problem. Interim instructions on disposal and decontamination have been issued (6). In general, present disposal procedures for most of the isotopes in use consist of:

1. Dilution of the radioisotope with a stable isotope of the same element.
2. Dilution in air or water.
3. Dilution and confinement, using a material like concrete for a diluting agent.
4. Concentration by evaporation, precipitation, or ion exchange, and confinement, as by burial.
5. Burial.

Specific interim recommendations have been given for the disposal of I^{131}, P^{32}, and C^{14}.

Sewage works superintendents and operators will be interested in brief

mention of just a few industrial uses for isotopes. Co^{60} has been used to detect flaws in cast valve bodies and welds, the thickness of coatings and materials, and for determining the liquid level in tanks. Ba^{140} has been used to detect changes in the grade of petroleum oil pumped through a common pipeline. C^{14} is a wonderful tracer of chemical reactions in research laboratories. P^{32} is being used as a tracer in agricultural plant studies. These and other isotopes have been used to check soil density at various depths, to determine the actual detention in flowing-through tanks, to study the dispersion of sewage effluents into bodies of water, to trace the flight of insects, and to locate sections of plugged pipes.

In medical therapy the urine from some irradiated patients is so radioactive that it must be handled with forceps and stored to permit decay before discharge to sewers.

As the use of radioisotopes by medical centers, industry, and research laboratories expands, the danger from careless or accidental discharge of radioactive materials to sewers and sewage treatment plants increases. Just as harmful discharges of industrial wastes may now inadvertently reach sewage treatment plants and streams, so harmful amounts of radioisotopes may be discharged. In such cases it is not merely a simple question of the quantity of isotope discharged. Also involved are its half-life, the types of radiation it emits, and the energy of the radiation. Unfortunately, radioactive material may accumulate in sewer slimes, such as *Leptomitus*, to a concentration many times the initial dosage. The sewage plant operator of the future will need to know how to use a radiac (radioactive) monitoring instrument and how to interpret the readings he obtains to measure possible adverse effects in sewers or in receiving bodies of water. Other problems he may eventually face because of carelessness or accidents in the disposal of isotopes will be the decontamination of radioactive pumping stations or sewage plant equipment, and the disposal of radioactive sludge.

Atomic Bombs

Atomic bombs may be a source of radiation. Air-burst atomic bombs will cause initial damaging radiation up to about 1 mi. from ground zero (the point on the ground directly below the center of the bomb burst). It has been stated that such a bomb will cause no appreciable residual radiation. This is true, but an exception may occur in the event of rain immediately following the burst or if the atmosphere is excessively dusty or smoky. As with ground, near-ground, or underwater bursts, monitors should always determine following air-burst bombings as a precautionary measure the radiological safety of all bombed areas, for rescue and fire-fighting operations.

Residual radiation sources, in addition to the fall-out of the fission products mentioned under "Nuclear Fission," include neutron-induced radioactive materials (within an area of about 2,400 ft. of ground zero in the case of nominal air-burst bombs) and unfissioned plutonium or uranium contained in the bomb. The neutron-induced radioactivity is relatively short-lived and the unfissioned products are largely an internal hazard. The fission products are the principal source of both external and internal residual radiation hazard.

Following an underwater, ground, or near-ground atomic explosion, sewage plant operators must be alerted to the danger of massive contamination of sewers and treatment plants. Radioactive sewage could occur from contaminated-soil runoff or as a direct result of the explosion. "Hot" sewers could also readily result from washing-down operations during decon-

tamination procedures, especially in sewers of the combined type.

How might an operator determine whether an air, ground, or underwater burst has occurred? In all cases a mushroom cloud will persist in the sky for some time following the explosion. This is a good indication that an atomic explosion has occurred.

In the case of an air-burst bomb, the ball of fire may be observed (followed perhaps by temporary blindness), blast damage will be extensive to above-ground structures with minor damage to sewers, and the residual radiation will probably be slight.

A ground-burst bomb will limit the above-ground blast effect, depending on the depth of the explosion. The damaged area may roughly be one-half to two-thirds of that of a nominal air-burst bomb. Underground damage to utilities, including sewers, however, will be much more severe. A crater at ground zero will be formed. In average soil, if the bomb exploded some 50 ft. under the surface, the crater might roughly measure 800 ft. in diameter and 100 ft. deep. Quite a hole! The burst will cause an earth shock similar to an earthquake. Serious residual radiation will be measured in the vicinity of the blast.

The underwater burst causes an even more limited area of above-ground blast damage, although shore installations may suffer seriously from wave action. The presence of a base surge (an oncoming mist or spray of radioactive vapor) spreading out from ground zero is the first indication of this form of atomic explosion. This base surge, which takes a few minutes to spread, depending on weather conditions, is deadly and all persons in its path must quickly seek shelter.

Radiological Warfare

Radiological warfare, another source of radiation, could conceivably be waged in one fashion by dropping gamma-emitter isotopes on a target area, but their production in any quantity would not be easy. Furthermore, their use would have to be repeated at regular intervals to be effective in keeping an area uninhabitable. Their principal effect would be psychological. If used, they would be a source of contamination to sewers and sewage treatment plants.

Contamination of drinking water with Sr^{89} is another possibility. The half-life of radioactive strontium is 53 days, it is a bone seeker, and emits beta particles. Water contaminated with stronium, if undetected by radiac instruments, would result in serious radiation injuries among the consumers. Protection of the public against such a disaster will depend on a knowledge of the normal background count of drinking water supplies and an adequate monitoring schedule.

Radiation Units

Just as the sanitary engineer has been accustomed to record his data in such terms as m.g.d. or p.p.m., so he must become familiar with the units used by the nuclear physicist in measuring radiations. Briefly the commonest units are:

1. The curie, c. This is the amount of radiomaterial that undergoes 3.7×10^{10} (37,000,000,000) disintegrations per second (d.p.s.) One gram of radium is equivalent to one curie. The millicurie, mc., = 0.001 c., or 37,000,000 d.p.s. The microcurie, μc., = 0.000001 c., or 37,000 d.p.s.

2. The roentgen, r., is the dose of X or gamma radiation that produces 2×10^9 ion pairs per cubic centimeter of air at standard temperature and pressure. The milliroentgen, mr., = 0.001 r. The roentgen is a quantity of radiation, but it may also be expressed as r. per min. or r. per hr., thus giving a rate of dosage. Thus, 5 r. per hr. for 5 hr. = 25 r. total dose.

3. Counts per minute give the measured disintegrations per minute

(d.p.m.) occurring among the atoms of a radioactive material. When such atoms disintegrate they may be detected by a scaler (counting machine) or on the dial of a Geiger survey meter as clicks or counts. Such instruments do not measure all of the disintegrations that are occurring, but only a certain percentage, known as the counting factor of the instrument.

Monitoring of Radioactivity

The purposes of monitoring with radiac instruments are to minimize external radiation, to measure cumulative exposure of an individual, and to detect contaminants in air, water, milk, food, and sewage, on surfaces, or in the body.

Area Monitoring

It has been recommended by federal authorities that areas in civil defense work be monitored immediately following an atomic bombing with a high-intensity instrument reading from 0.025 to 500 r. per hr. and later be monitored for final clean-up work with a low-intensity instrument reading in range scales from 0 to 50,000 mr. per hr. Such radiac instruments measure the radiation intensity by the ionization produced by such radiation in a gas contained within the instrument. These instruments require periodic calibration by checking their scale readings at various distances from a radioactive material of known strength. Area monitoring, in most cases, will not and should not be a function of sewage works personnel.

Personnel Protection

An individual's cumulative exposure to radiation is measured by dosage devices, such as film badges or dosimeters. A film badge after development gives a density reading with a densitometer and the reading obtained may then be converted to the roentgen dosage received by the film badge wearer by means of a calibration curve.

Dosimeters are small fountain-pen size charged condensers that discharge their current as the contained gas in the chambers is ionized. A pointer and scale reading (in milliroentgens or roentgens) give the total radiation exposure of the individual.

In emergency operations following atomic bursts, where residual radiation is found to be present, sewage works personnel should have the protection of one or both of these devices.

Detection of Contaminants with Scalers

Scaler or counting instruments measure the disintegration rate of the atoms in radioactive substances, and read in counts per minute. They might be likened to sewage flow recorders for Parshall or Venturi flumes. The flume is the flow measuring device, but the recorder registers the quantity of flow in a given time interval. Likewise, a radiac scaler or counter registers the quantity of radiaton in counts or disintegrations per unit of time, as measured by a Geiger circuit. They do not measure the total number of atoms that are disintegrating, but only a certain percentage. The per cent that will be counted depends particularly upon the position or distance of the radioactive sample from the measuring (Geiger) tube and on the thickness or volume of the radioactive sample. Other more complicated considerations also enter into the counting factor. Most end-window Geiger-Mueller counters, by putting a sample on the top shelf of a lead-shielded container, known as a pig, will, when counting beta particles, give a count which never exceeds 25 per cent of the total disintegration rate. One can obtain this counting factor for any instrument by calibration against a known standard.

Scalers are for use primarily in laboratories where precise measure-

ments of radioisotopes or fission products at or above background counts are desired. By evaporation, for example, of low-activity samples of sewage, sufficient concentration of radioactivity in the residue is obtained to measure very low radiation levels with scalers. (The background count refers to radiation due to cosmic rays from outer space, to radioactive materials normally in the vicinity, and to a slight radioactive contamination from the materials of which the measuring instrument is made. The background at sea level is normally not more than about 0.04 mr. per hr., or about 25 to 30 counts per min.)

Detection of Contaminants with Geiger Survey Meters

Portable Geiger survey meters are suitable for measuring permissible emergency radiation levels in sewage, as well as for monitoring food, water, milk, personnel, and surfaces contaminated with radioisotopes or fission products. One such meter on the market, using low-voltage batteries replaceable at a cost of less than $4.00, will measure alpha, beta, and gamma radiations. This is accomplished by an interchangeable gamma-beta probe and end-window alpha probe. The meter also can be operated in the proportional range so as to measure alpha radiations only. Equipped with an insensitive Geiger tube, the instrument will also read up to 5 r. per hr. radiation, which makes it suitable for use as a low-intensity area-survey meter.

Although a variety of excellent and sensitive radiac instruments are available for various uses in radiological work, the entire instrument field is under intensive development. New and improved instruments may be expected, especially simplified rugged instruments at probably much lower cost. The many interesting possibilities in this field are beyond the scope of this paper.

Contamination and Decontamination

Radioactive matter from isotopes in peacetime, or as a result of radiological warfare or atomic bombing, may contaminate surfaces, human bodies, food, water, milk, or sewage. Because the dangerous portion of radioactive material is the nucelus of the atom, it cannot be destroyed or rendered harmless by any chemical means, such as neutralization or disinfection. The contamination must be removed, just as dirt or dust is removed, or it must be rendered harmless by shielding, burial, or extreme dilution to reduce the intensity of the radiation to a safe level. Contamination of surfaces, streams, sewers, sludge, and sewage effluents is of direct concern to sewage works officials. The contamination of personnel and food is of secondary concern.

Surfaces

In addition to the possible need of decontamination of sewage plant equipment, the decontamination of other structures and outdoor areas may well require in wartime the services of sewage works personnel working under the direction of Public Works Departments.

Normally, a surface should be considered contaminated if a radiation count of twice background is obtained. In emergencies, such as war, a much higher tolerance would be permitted. The contamination may be lightly held on the surface, embedded, as in porous materials like stucco, or chemically linked with electrons in the surface material.

Before starting decontamination procedures in danger ("hot") areas following a nuclear blast, the safe working period for personnel must be considered. In this connection, W. C. Orr, at the University of Connecticut, has developed a circular slide rule for the Connecticut Civil Defense Department that gives the dosage exposure to area workers for any length of time,

based on the multiple half-life equation involved. The use of this rule simplifies determination of safe exposure periods for personnel.

What constitutes over-exposure in times of emergency? The peacetime maximum permissible exposure to external radiation is 0.3 roentgens per week, or 60 milliroentgens per day for a 5-day week. For internal radiation the objective is zero intake. In war, exposures must of necessity be much higher, depending on the urgency of the situation. White blood cell changes and genetic effects would occur with a whole body exposure of 100 roentgens, but no symptoms of radiation sickness would occur. It might be acceptable to expose workers to a total dosage of 25 to 50 roentgens before withdrawing them from emergency work. The 50-r. emergency limit is tacitly substantiated by a preliminary report of an AEC project at the School of Medicine, University of California at Los Angeles. The report suggests that 50 r. be used as a limit over a 56-day period, and bases the dosage on the decay phenomena of an A-bomb explosion.

Decontamination procedures for surfaces are as follows:

1. Porous articles, like rope, are very difficult or impossible to decontaminate and must be buried or shielded until the radioactivity has decayed to a safe level. The same would be true of badly contaminated clothing, rugs, curtains, and upholstered furniture. Laundering may be effective for light contamination.

2. Household cleaning and scouring compounds, detergents, paint cleaners, and ordinary soaps will all help to remove radioactive particles from surfaces. These materials are safe for most surfaces, are non-hazardous, and do not call for particular experience in their application. Trisodium phosphate is said to be especially effective for removing radioactive rare earth elements and yttrium, believed to constitute 30 per cent of the long-lived isotopes present after a nuclear burst.

3. For greasy or oily surfaces, dry cleaning solvents, kerosene, carbon tetrachloride, or gasoline may be used; if flammable, the fire hazard these substances create must be borne in mind.

4. Exposed surfaces in cities covered with "industrial films" of grease and dirt may be effectively decontaminated with a live steam and detergent mixture.

5. Buildings of strategic importance with a high-level external surface contamination may be partially decontaminated by hosing down with water, working from a position in the interior where the activity will usually be less and the walls can be utilized as a shield.

6. Caustic pastes (alkalies) are effective cleansers of painted surfaces. The heat evolved from some materials, such as caustic soda, is often advantageous if the treated surface will not be too seriously damaged.

7. Methods employing abrasion, especially wet sandblasting, are effective physical means of surface removal of contaminants. This procedure leaves large volumes of radioactive sand and water for safe disposal. Depending on the type of surface and conditions, sawdust, steel wool, wire brushes, and various polishing or buffing machines might be used. Actual removal of some of the surface, if dimensional changes are permitted, may be necessary (as by planing). Highly contaminated porous materials, like stucco, will undoubtedly require removal and burial. Stucco buildings are particularly vulnerable to the base surge from water-burst bombings.

8. Surfaces emitting only alpha and most beta particles from fission products might be painted, a procedure that will shield the damaging radiation.

9. After an underground burst, a dry fall-out is likely. It may be better

in such a case to employ dry physical methods, such as vacuum cleaning or brushing, as an initial step to prevent the spread or stronger attachment of the contamination to surfaces, which may result after wetting.

10. Adhesives are practical for removing loose radioactive dust or mechanically held contamination. Strippable plastics or adhesive tapes of different kinds may be applied and then stripped off, taking with them much of the radioactive material.

11. Contaminated streets might be hosed down, with due consideration to the effects on the receiving body of water, or swept, and then covered with asphalt. It is realized that repaving work may not be immediately practicable.

12. Non-critical areas can be roped off and the radioactivity allowed to decay to a safe level.

13. One of the best solvents for decontamination of clothing, wood, and other organic materials is a hot 3 per cent citric acid solution. A mixture of phosphoric acid, chromic acid, and a wetting agent should be used for decontaminating metals susceptible to corrosion by hydrochloric acid; otherwise 5 parts of hydrochloric and 1 part of citric acid may be applied for a short bath of a few minutes.

14. Soils tend to concentrate radioactive material. In one sense this is fortunate, but in parks or lawns of contaminated cities the top few inches of soil may require removal or it can be covered with a foot of fresh soil. After wetting the soil the contamination might be effectively buried by plowing.

It is obvious from the many methods of decontamination listed that considerable judgment will be needed as to the best method or methods to use. The discharge, for example, of large volumes of radioactive waste water to a river (even if diverted from the sanitary sewers and sewage treatment plant) would be undesirable to say the least, if the river were used by a downstream community for drinking.

It should be re-emphasized that radioactive materials cannot be destroyed or neutralized. Nevertheless, the spread of the contamination must be prevented. "Hot" areas must be posted and roped. Great care must be exercised in the disposal of contaminated objects, of waste water, and of waste materials. Sandblast material, for example, should be covered with cement and later buried. In many cases the contamination is merely moved, with or without dilution, from one place to another.

Human bodies

A decontamination center for sewage works personnel who have been working in radioactive areas will be a necessity. Contaminated personnel must remove contaminated clothing and wash themselves, possibly many times, with soap and water, paying particular attention to the hair, nails, skin folds, and body openings. A mixture of barium sulfide and starch will remove material held tenaciously by the skin. After monitoring with a Geiger survey meter, clean personnel don clean clothes on the clean side of the center. The waste water from "change" stations should be held in tanks for decay before discharge to sewers or a field. Washing machines for clothing eventually require decontamination or burial.

Decontamination workers should wear protective clothing, of rubber if necessary, rubber boots, a hood, and gloves. If sprays or dust are produced in the operations, goggles and a respirator must be worn. Protective creams may be rubbed on the skin. Film badges and dosimeters should be worn. Workers should not smoke in contaminated areas and preferably should refrain from eating.

Food

Although the monitoring of food following nuclear bombings will be the responsibility of others, for their own personal protection sewage works personnel should have a general knowledge of the hazards involved.

Following an air-burst bomb, food inside buildings which have remained intact should be safe for consumption. If exposed food is located in buildings where the windows were left open or the roof has been damaged, it should, if within 1 mi. of ground zero, be viewed with suspicion and monitored with a Geiger survey meter before use.

Properly covered foods, such as canned, bottled, or refrigerated foods, will probably be safe for consumption in all locations with all types of bomb bursts. The containers of such foods within the contaminated area should, however, be thoroughly washed with soap and water before removing the contents.

Induced radioactivity in food from neutrons is considered very unlikely; first, because most of the activity would be very short-lived, and secondly, because the neutron flux from an exploding bomb falls off rapidly (maximum distance about 2,400 ft.), so that most so-exposed foods would be destroyed by the heat and blast effects of the bomb. Likewise, gamma rays passing through food will not spoil it. The only danger of much import is the contamination of surfaces from fission products (beta and gamma radiation) and unfissioned uranium or plutonium (alpha radiation).

Bagged and other absorptive materials containing foods, such as sugar or flour, may or may not be contaminated. If the roof of the storage warehouse is intact there is less likelihood of fall-out on the food. Within 1 mi. of ground zero (further, possibly, for water bursts) such foods should be monitored. If contaminated, only the outside bags in a pile may need to be destroyed, or they might be held for decay of the radioactivity.

Outer layers of meat may be affected and could be cut off. The milk from cows in the exposed area could possibly become radioactive from the animals feeding on contaminated vegetation and, therefore, should be checked. Contaminated cattle, sheep, or hogs can be salvaged for food by

TABLE I.—Permissible Levels for Radioactivity in Drinking Water or Food[1]

Authority	Use	Radiation		
		(μc./cc.)	(d.p.m./cc.)	(mr./hr.)
"Effects of Atomic Weapons," p. 332, par. 10.65	Accepted safe tolerance level for water containing fission products. (Many times tolerance values given, considered safe for limited use.)	4×10^{-6}	8.88	0.04
U. S. Atomic Energy Commission	Permissible recommended limit for peace-time use	1×10^{-7}	0.22	—
W. F. Bale, University of Rochester	Temporary emergency consumption	4.5×10^{-4} to 2.2 to 10^{-3}	1×10^{3} to 5×10^{3}	—
J. B. Hursh, University of Rochester	Temporary emergency consumption	5×10^{-2}	1.1×10^{5}	—

[1] Because the volume of foods or milk consumed per day is usually less than the volume of water, the same levels would be applicable to them.

destroying the hides and internal organs.

The level of contamination permissible for food and drinking water in wartime is given in Table I. On the premise that the level of radioactivity that can be permitted in water will, in general, be inversely proportional to the time this water is used for human consumption, Table II has been formulated by the AEC to furnish guidance as to acceptable values of radioactivity in water during a period of emergency immediately following a nuclear explosion.

It is emphasized that these are not peace-time permissible limits of radioactivity for either long-term or short-term consumption. Responsible officials can utilize these values during periods of emergency with the conviction that water or food with radioactivity falling below these limits can be used with no great hazard.

The beta-gamma values do not apply for periods later than one month after a nuclear explosion, as the longer-lived radioactivity remaining carries an increasing hazard for human consumption.

A portable Geiger-Mueller survey meter with a thin-wall beta-gamma tube probe could be used as a rough check for determining the radiation in water or food contaminated at the emergency permissible values. A surface reading with such a tube will detect contamination, or a submergence-type tube might be used. However, it has been pointed out that submergence-type tubes might not detect a change in activity of the water until it reached dangerous levels. Once used in water contaminated with fission products, it is felt that such tubes would be very difficult to decontaminate. The AEC is currently working on a more sensitive submergence-type tube, which will have no decontamination problem. Details are still restricted.

The portable Geiger survey meter discussed under "Monitoring of Radioactivity", when used with an end-window alpha tube, is an excellent field instrument for determining radioactivity in water or food down to a point approaching the background level. The use of this instrument presents no tube contamination problem.

TABLE II.—Acceptable Radioactivity in Water During Emergency Period

Length of Time Water is to be Consumed	Beta-Gamma Activity		Alpha Activity	
	(μc./cc.)	(d.p.m./cc.)	(μc./cc.)	(d.p.m./cc.)
10 days	9×10^{-3}	2×10^{3}	5×10^{-3}	1.1×10^{4}
1 month	3×10^{-3}	7×10^{4}	1.7×10^{-3}	3.7×10^{3}

Streams and Sewage Effluents

The contamination of streams might occur from the fall-out particles of an atomic bomb either dropping into a river or accumulating on the watershed. An atomic bomb might also be exploded in or near a stream, or radioisotopes, such as strontium mentioned earlier, might be deliberately put in the water. The discharge of isotopes to rivers or sewers in peacetime constitutes another source of contamination to either streams or sewage.

When the normal background counts of water or sewage are desired or when the radioactivity of the water or sewage is very near background, samples should be evaporated to dryness and the residue counted in a suitable laboratory scaler-type instrument. It might be necessary to concentrate from a pint to many gallons of the water or sewage, depending on the level of its activity.

Decontamination of water and sewage from nuclear bombings proceeds by natural means rather rapidly as a result of dilution of flow, natural decay, and adsorption of the radioactive materials by suspended and colloidal matter usually present. The interior surfaces of sewers and sewer slimes also adsorb radioactivity, although the latter may cause a delayed problem

when they slough off and discharge to sewage treatment plants or streams. Water or sewage will probably not be above the permissible limit for more than a few days as a result of an atomic bombing near the water.

Chlorination of sewage is of no value in decontamination. Activated sludge treatment removes much radioactivity, but the sludge is then radioactive and must be safely disposed of. Furthermore, overdoses of plutonium are said to affect activated sludge. Chemical precipitation, where employed, will also remove varying amounts of radioactive isotopes, but presents the same problem of a resulting radioactive sludge.

It should be pointed out that all waters and sewages have a natural radioactivity, which might be called their normal background count. A proper step in evaluating the degree of radioactive contamination from accidental or deliberate causes is, therefore, to make measurements of this normal background. The tests should be repeated periodically. A radiac monitoring set-up for streams and sewage effluents, as well as the present checks on the physical, chemical, and bacteriological quality of water and sewage, will be a coming necessity, especially where streams or sewers subject to industrial pollution are involved.

The "Interim Instructions" (6) give the permissible concentrations for I^{131} and P^{32} in sewage. In order to see that the present limits are not exceeded, the sewer discharges from users of these radioisotopes should be monitored.

If the accidental discharge of a highly radioactive isotope occurs to sewers tributary to a treatment plant, or if a ground or underwater A-bomb burst occurs in the vicinity of such sewers, not only must the possibility of radioactive raw sewage, sewage effluents, sewers, and pumping station sumps be considered, but the sewage treatment plant equipment and sludge should be monitored for possible harmful radioactivity. In the case of radioactive sludge, such sludge might be dangerous to use as a soil conditioner, depending on the radioisotopes present.

The effect of improper isotope disposal or atomic bombings on streams, other than their use as sources of domestic water supply, involves many considerations. The repeated ingestion of radioactive fish for example, may result in harmful accumulations within the body. Waste isotopes may create a hazard to swimmers. Use of contaminated process water would ruin some manufactured products, such as photographic film.

Because radioactivity will tend to concentrate in stream organisms, an examination of plankton, algae, fish, and worms for radiation effects is desirable. Kochtitzky and Placak (1) state that there is no obvious harm to aquatic organisms from radioactive wastes and that algae in particular are very tolerant of them.

About the only treatment available at present for such wastes in streams is natural decay or extreme dilution. The permissible limits of radioactivity in streams will be a job for the National Committee on Radiation Protection. Likewise, piers, boats, and mud might concentrate such wastes. Special methods of testing animals and objects are being developed by the Oak Ridge National Laboratory and include the so-called flounder, mud, fish, and well probes, and autoradiography. Simple mixtures of isotopes may be identified by energy and decay time measurements. In other cases, chemical separation of various radioisotopes may be necessary. This is time consuming and requires the services of a radio chemist. A Geiger-Mueller tube, float-operated and shielded and kept at a fixed elevation above the water, holds great promise.

Use of such a device would be simplified in the effluent channels of sewage treatment plants where the water level can be kept nearly constant. Because of the low level of activity, however, large volumes of sewage will need to be passed under and around such tubes.

Conclusion

It has been the purpose of this paper to point out to sewage works superintendents and operators some of the peace-time and war-time problems they may face in the radiological field. A knowledge of basic nuclear physics and practical experience in the use of radiac instruments will be a coming necessity. Operators should avail themselves of current training courses in preparation for a possible future need of knowledge in this field.

Acknowledgment

In the preparation of this paper the author has drawn on the material presented in an excellent radiological health training course, which he attended, given under the direction of Dr. Simon Kinsman, chief, Radiological Health Training Section, Environmental Health Center, U.S.P.H.S., Cincinnati, Ohio. For this background information he is indeed indebted.

Appendix A

Recommended Reading on Radiological Problems

1. "Radioactive Contamination as a Factor in Stream Sanitation Studies," by O. W. Kochtitzky, Jr., and Oliver R. Placak, Oak Ridge National Laboratory, Oak Ridge, Tenn. (Write authors for copy of paper.)
2. "The Effects of Atomic Weapons." U. S. Dept. of Defense and U. S. Atomic Energy Comm. For sale by Supt. of Documents, Washington 25, D. C. $1.25 (Sept., 1950).
3. "What You Should Know About the Atomic Bomb." Surgeon General, Army Medical Dept., Pentagon Building, Washington 25, D. C.
4. "Radiological Defense." Vol. I and III. War and Navy Departments, Armed Forces Special Weapons Project, Washington, D. C. (May be difficult to secure.)
5. "Surveying and Monitoring of Radiation from Radioisotopes." U. S. Atomic Energy Comm., Washington, D. C. (June, 1949).
6. "Isotopes Catalogue" and other supplemental information; also, "Interim Recommendations for the Disposal of Radioactive Wastes by Off-Commission Users, Circular B-6." U. S. Atomic Energy Comm., Oak Ridge, Tenn.

THE DAILY LOG

Marion, Indiana

By David P. Backmeyer, *Superintendent*

September 6—Two fishermen stopped in at the plant to report great numbers of dead fish found in the river below the plant outfall. An inspection trip with two of our local conservation officers revealed a complete kill in the river for a distance of about four miles downstream. Chemical tests made in the laboratory showed that considerable quantities of cyanide had passed through the plant, with plant effluent samples on two days contain-

ing in excess of 3.0 p.p.m. HCN. A checkup at local industries to locate the source of the poisonous material did not meet with much success at first. However, when some of our clients (who like to spend their evenings on the banks of the Mississinewa) learned what was doing, we soon had several hot clues to trace down. One of our local industrial plants had cleaned out its electroplating room, and as the city sewer was the most convenient place to flush the residue, in it went! This incident received sufficient publicity so that we don't look for a re-occurrence in the near future.

September 17—Our "old reliable" double piston plunger pump was in need of complete repacking. At least four different kinds of packing have been tried on this pump, each one highly recommended by the particular salesman who assured us he had the best product for this job. Our maintenance record shows the last installation of ¾-in. neoprene was far superior in performance to anything used previously. Our operators cut the rings to fit the piston, and a continuous water stream directed at the top of the gland serves as the lubricating agent when the pump is operating.

September 18—This is the month when our canning plant troubles get to be a real burden. A man has been stationed at the outlet flume of the tomato packing plant to get a composite sample of the waste over an 8-hr. period. The B.O.D. of this flow varies from 700 to 1,500 p.p.m. Three of our four blowers are needed on continuous operation, providing 1.8 cu. ft. of air per gallon of raw sewage. A flare-up in the activated plant seems to be inevitable. If no relief is forthcoming from the weatherman, it will be necessary to by-pass about a third of the flow from the primary tanks directly into the river.

September 22—On three occasions we have had mechanical difficulties with the drive units on our final settling tank Tow-Bro collectors. The gear reducers are now protected with sheet-metal hoods, so that even the most severe driving rainstorm will not affect the oil-lubricated gear boxes. A ground in the 440-v. feeder line was the cause of the latest interruption. At the suggestion of our chief operator, a complete utility unit was assembled, consisting of the spare gear reducer (bought about a year ago for just such an emergency) and a new motor operating on 110-v. current. In an hour's time this replacement unit was connected in place and in operation. Following repairs to the 440-v. equipment, the utility drive was returned to the stock room.

September 28—Jack Smith, foreman of Garbage Collection Department, investigated an unusual noise at our primary settling tanks, and found our big collie dog swimming in the east pre-aeration tank. After rescue operations were completed, the pooch was given a thorough soap and water treatment. If he must drink sewage instead of water (and we know of several dogs that seem to have a preference for the former) we hope he will trek back to the final effluent ditch and partake of the finished product.

September 30—We were pleased and honored to spend a few hours with two distinguished foreign visitors who stopped to see our treatment facilities. Mr. and Mrs. Ingmar Gullstrom, Bureau of Water Supply and Sewerage, Stockholm, Sweden, seemed to be much interested in all the details of the science of sewage treatment as practiced in this country. We were particularly grateful to these folks for their interest in our prolific mushroom crop, which was at its best. We now know that in the past we had been destroying a delicious edible food, which grows voluntarily on our front lawn each fall. Incidentally, this lawn has been treated several times with liquid sewage sludge.

October 10—We have several orders ahead for application of liquid sludge. This service is now rendered 45 customers living within a radius of 5 mi. of the treatment plant. Our big need is to develop a means of applying the sludge economically when the weather is wet and the trucks cannot drive on the farm fields. High-pressure pumping is under investigation, but the costs involved appear to make this method impractical.

October 11—Pumpage of raw sewage decreased about 15 per cent, due to shutdown of the ketchup processing plant and the decrease in the amount of air conditioning water consumed. Several of the city's business buildings do not have access to a storm relief sewer; therefore, air conditioning water is mixed with sewage and treated at the plant. This source of volume load could develop into a serious problem. The customer resents paying for treatment of his waste, which needs no treatment until it is contaminated in the sewers, and the treatment plant facilities are not adequate to handle unlimited volumes of dilute sewage. What would have been the reaction of our citizens of 50 years ago had they been advised to separate their storm water from the sanitary flow throughout the entire sewer system? Such installations in the downtown business areas are almost impossible to construct today.

Within another 30 days the weather will be such that outside work will be most disagreeable. We plan to clean up our outside painting jobs during the last two weeks of this month. Railings, walkways, skylights, gratings, roof drains, roof ventilators, floodlights, and most other outside equipment will be inspected and serviced if necessary. The plant operators now keep a daily "log" for spotting in advance the necessary maintenance items which they know must be cared for on a seasonal schedule.

October 29—Our truck driver went to sleep at the switch and gave himself a bath in liquid digested sludge. The loading line, which is above the level of the tank trucks, was not placed in proper position prior to starting the pump from the remote control switch. This incident probably will not reoccur soon!

November 10—Our full operation force turned out for a special meeting, at which we spent a couple hours mulling over the answers to some 58 questions pertaining to maintenance problems in our own plant. Army Manual TM5–666 served as text and guide for answers to most of the questions of general nature. We should have a similar session every six months.

November 15—Letters were sent out today advising local contractors of our proposal to construct a third digestion tank at the plant site. Legal advertisements will follow in the local papers and in the construction trade magazines. This addition is to be financed from accumulated surplus earnings. On several occasions some of our politically-minded friends have suggested good ways of spending this money. We are fortunate that opposition to such practices has been strong enough to protect our earnings. The record of the digester tank loading and operation during the past seven years tells a pretty convincing story. The influx of heavy garbage loading in August and September is responsible for a goodly portion of our troubles. Today's sample of "digested" sludge contained only 2.0 per cent total solids. Volatiles could be greatly reduced by an additional 15-day holding period in the heated digesters, as has been established by several experimental tests.

November 18—Our gas-fired heating boiler was dismantled and thoroughly inspected. This unit burns only sewage gas. The burners were removed for brushing and adjustment. Automatic controls, diaphragm-operated regulators, and valves were serviced. A note is carried on the desk log to check the

inventory of all diaphragms used in the sewage gas control system, keeping a reserve of at least one spare for each type of regulator or valve. A rotted-out diaphragm on the dome of the primary digester gave us a lot of grief a couple years ago. We were caught with our replacement stock depleted, and considerable work was required to devise a make-shift substitute.

November 24—Plans were completed to have a temporary sludge lagoon constructed on the one-half acre strip of land adjacent to our primary and aeration tanks. This is one messy site we had hoped we could get along without. If and when we get the additional digestion tank constructed and in use, the lagoon area can be cleared of the accumulated sludge solids. We spend considerable money in an effort to keep our front yard in the best possible shape from the standpoint of appearance. The pond of sludge at the rear of the plant will have to be concealed in some manner, as it certainly will not enhance the beauty of the general layout.

December 3—We have made repeated tests with the raw sewage pumps in an effort to find what appeared to be a fault in the metering device on the main raw sewage line. Today we discovered the cause of the trouble. A valve on a branch line connected to the pump discharge header was left open, permitting part of the flow being pumped to by-pass the meter entirely. This had been a puzzler for several months, now we wonder why such an obvious cause of the trouble wasn't detected a long time ago.

December 7—A change in operation routine will be made to assure maxi-

FIGURE 1.—Scale and corrosion in inlet end of exchanger for heat recovery from gas engine exhaust gases; brass tubes had been in use 51 months.

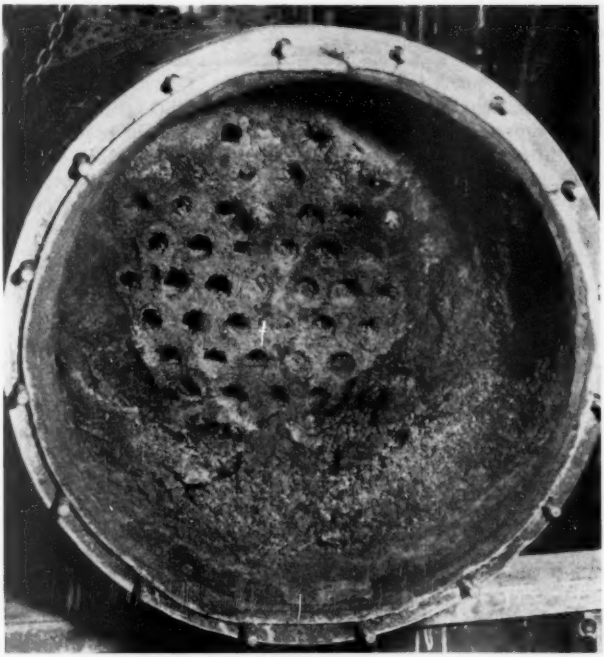


FIGURE 2.—Scale and corrosion in outlet end of exchanger for recovery of heat from gas engine exhaust gases. Unit was rebuilt using stainless steel.

mum concentration of raw sludge being pumped to the digesters. All raw sludge will be drawn through a telescopic sight valve and into a well prior to pumping to the plant digesters. This system enables the operator to accurately control the flow of the raw sludge to the well at all times. To perform this duty in the summer time requires an above average degree of intestinal fortitude. The odors emitted are not conducive to development of a vigorous appetite.

December 11—A special 4-in. line has been installed that will permit us to pump and re-circulate sludge from the primary digester to the dome of the tank. It is hoped that this procedure will control scum formation under the cover of the tank. Intermittent operation of the circulating pump has resulted in freezing of the new line in severely cold weather. The pump is now operated 20 hr. each day, and the pipe has been covered with insulation material to stop any further trouble of this kind.

December 15—Aeration tank No. 4 is being drained and taken out of service for the immediate future. Excessive rainfall in the late winter and early spring months results in a greatly reduced sewage load. Every effort is made to tailor our treatment accordingly, and economize on air to the fullest extent. The flows in the receiving stream are usually ample during this period to allow us to hedge some on the quality of the effluent discharge. These economy moves can mean several hundred dollars saved in operation costs. We'll need this money next October when the canning plant wastes require the use of electric-

driven blowers to augment those driven by the gas engines.

December 17—The tubes in the heat exchanger were 51 months old today. The record of the age of the tubes is kept so that comparison may be made between the brass tubes now in use and the steel ones formerly used.

December 27—We know now that the most unusual conditions can and do occur in these heat exchangers (see Figures 1 and 2). In addition to the loss of the brass tubes, which outwore the steel tubes five times, replacement of the heads of the exchanger was necessary. Our local steel fabrication plant rebuilt the exchanger, using stainless steel in place of boiler steel. Additional hand-holes were cut in to allow inspection of both ends of the exchanger and permit periodic flushing of the entire inside. The cost of the rebuilding job was less than half the cost of a standard new unit.

EXPERIENCE OF TWO OHIO CITIES IN TREATING INDUSTRIAL SEWAGE*

I. Fremont, Ohio

By John S. Hess

Superintendent, Sewage Treatment Plant, Fremont, Ohio

At Fremont, Ohio, industrial wastes comprise a very significant part of the sewage demanding treatment at the municipal treatment plant. By volume, depending on the season, from 10 to more than 50 per cent of the flow issues from manufacturing concerns and food processing plants. The population equivalent of the industrial wastes entering the sewers sometimes reaches twice the connected resident population of the city. These peak loads occur intermittently, and at odd hours of the day and night, subjecting the plant to staggering shock loads, which sometimes nullify the effectiveness of some of the treatment units for several days.

Daily composites of hourly samples, taken in proportion to metered flow, show such wide variation in strength that it is difficult to choose a dilution ratio suitable for routine oxygen demand determinations. Multiple dilutions are used when variation is suspected, but the occurrences are usually of a surprise nature. To cite an example, Feb. 2, 1951, (not in the tomato or cabbage harvesting season) produced a composite sample with a B.O.D. of 860 + when a 100 to 1 diluted sample came out depleted. On Feb. 3, the 5-day B.O.D. was 175. Again, on Feb. 4, a sample was depleted although there was nothing in the physical appearance to indicate that a higher dilution might be necessary.

Types and Sources

The wastes at Fremont are as varied in type as they are in momentary strength. They may be classified as follows:

1. Food processing wastes.
   (a) Recipe products preparation and canning wastes (tomato catsup, vegetable soups, beef and chicken noodle soups, mincemeat, etc.)
   (b) Canning wastes (sauerkraut).
   (c) Dairy and milk receiving station wastes.
   (d) Cheese plant wastes.
2. Plating wastes (job plating plants

* Presented at 25th Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Columbus, Ohio; June 20–22, 1951.

and product plating departments in cutlery and drop forge industries).

3. Acid pickling wastes (several metal-working industries operating pickling tanks).

4. Chemical wastes from dry-battery manufacture.

5. Coolants and oil-bearing degreasing wastes.

Naturally, all these sources have been contacted and informed regarding the individual responsibility each must assume for the wastes he discharges into the sewers. However, whether by accident or by intent, unacceptable wastes do appear in the sewage without warning and without leaving undeniable evidence as to their source.

Oil

To detect oil, small paddles, well-painted with a light-colored corrosion-resistant enamel, are floated at the ends of lines in manholes at strategic points in the sewer system. These have worked quite satisfactorily in leading directly to the offending party. Food processing wastes are considered acceptable if discharged before becoming septic and if in reasonable amounts. They are easily recognizable as to source, and most of the plants have been very cooperative in pre-treating or following out any request the city might make.

Acids

The discharge of un-neutralized acids into the sewers presents the greatest remaining problem. Detection and collection of undisputable evidence at the source without the use of expensive pH recording equipment has posed a most knotty problem. A device now being developed would collect a sample and at the same time discharge an easily recognizable amount of fluorescein dye into the sewage stream whenever lowered pH triggered the mechanism by allowing a filament of acid-soluble material to dissolve. The success of the gadget now depends upon finding a material with reasonable tensile strength when submerged in neutral or alkaline water, but which will dissolve rapidly in acid water.

Acid wastes have reached the plant in sufficient strength to neutralize the normally high alkalinity of all the rest of the hourly samples in the daily composite. The trickling filters have been rendered completely ineffective, and reasonably luxuriant growths of zoogleal gel have sloughed off in large amounts after some of these sieges by acid wastes. In a plant where combined sewers subject the filters to periodic doses of storm runoff water, and the growth is usually clinging precariously to the stone, this weakening by the "acid ordeal" is especially serious. Naturally, no industry admits to dumping acid in such quantities into the sewers. Potential suspects are so many and the lag before detection at the plant is so great that only a system of detection devices such as that previously described could seem to offer hope of pointing a finger at the real culprit and making it stick.

Oil Troubles

Oil has only been briefly mentioned as a troublesome industrial waste. It is hoped that the future will bring no new experiences to justify more than a mere mention of oil. From the time the Fremont plant was started (August 1949) the afternoon and night operators would occasionally report oil in small slugs at odd hours. This did not give cause for much alarm, because it seldom lasted more than a few minutes and it was easily handled by the mechanical skimming device on the primary clarifier. Neglected traps at gas stations or factories or accidental spillage near catch basins might account for most of these occurrences. However, attention was called to the prohibitory clauses in the sewer ordinance by means of short publicity releases in the local newspaper.

On November 28, 1950, during a week of "big snow," oil began appearing in quantities sufficient to cause alarm. The plant was finally by-passed, but not before enough oil had accumulated to require a week of scrubbing, skimming, and hosing to put the plant back in shape for operation. The oil was of a specific gravity so near that of water that the least agitation submerged it enough to pass under the scum baffles. The oil was soon traced to its source at a large drop-forging plant. During the cold weather, the No. 5 fuel oil, kept in outside storage tanks, had to be preheated to facilitate pumpage. A steam coil submerged in the tank had cracked, and the steam entrained sufficient oil to overtax the existing trap, which had been installed to recover cylinder oil entrained in the exhaust steam from the hammers. The plant superintendent gave assurances that this would be corrected and immediately set about installing a series of additional chambers to increase the capacity and efficiency of the trap.

Things went along pretty smoothly until January 4, 1951, when we were again deluged with oil. This time the oil came intermittently, but in much greater quantities than before. Repeated calls to the plant which had caused the November mess brought assurances that their traps were clean—"It must be some other plant this time." Repeated inspection at a manhole just outside this concern's property failed to disclose any unusual amount of oil on the surface of the water, although the painted float was badly soiled. This could have been the cumulative effect of a light film of oil, which always carried through the traps. Orders were left with the night operators to call, regardless of the time, if oil appeared. The plant was kept in semi-operation between slugs of oil as much as possible. Finally at 2:30 one morning a call came that oil was starting. Inspection at the manhole showed plenty of oil flowing right then, but delays at the gatehouse in getting the night superintendent resulted in uncovering a relatively clean manhole by the time plant personnel were on hand to be shown. An all-night watch was kept, with maintenance men patrolling the manholes. Right after the night shift went off, oil was discovered in a sewer supposed to carry only sanitary sewage from the lavatories. It was discovered that the oil, which was preheated in the storage tanks, was circulated through a loop of pipe past all the forges and then back to storage. About halfway around the loop, a heat exchanger had been installed to replace heat lost through the uninsulated walls of the pipeline. The steam trap on this heat exchanger discharged condensate into a sump connected to the sanitary sewer. Vapor surrounding the sump prevented observation of a stream of oil flowing through a ½-in. pipe under 65-lb. pressure. Shift-end wash-up periods provided the flush-tank effect to give intermittent scouring of this sanitary sewer with its heavy flow of oil.

Filter Troubles

After a week of cleaning up, the sewage treatment plant was apparently ready for operation again. However, it was soon discovered that the filters were ponding and that a gray stringy fungus, which looked like the *Leptomitus* associated with decadent stream conditions, was supplanting the normal growth.

A heavy shock dose of emulsified ortho-dichlorbenzene was introduced and recirculated through the plant for a day before being slowly discharged to the river. This seemed to help slightly, but an examination of the filter media below the surface disclosed a tight layer of a black oily substance about 8 in. down. Breaking through this permitted water to drain away from an area immediately surrounding the spot examined.

A tool was devised to loosen this layer all over the filter. Four feet of

1-in. pipe was fitted with an ell at the top and a 1-in. to ¼-in. reducer on the bottom. This formed a probing nozzle, with which the operator could direct the stream from a 1-in. hose on the layer in a small area immediately surrounding the point at which the nozzle was worked down through the stone. Although this was admittedly a tedious process, the "filter-bazooka" successfully opened up the filters and soon a normal growth had replaced the fungus. The filters have steadily increased in efficiency and now are producing an effluent of a quality commensurate with the high-rate filter operation experienced elsewhere.

Incidentally, the writer has found a greenhouse operator who considers sludge with a bit of fuel oil on top a strictly premium product. The Fremont plant, it appears, will be able to supply that vital ingredient in its sludge for some time to come.

II. Celina, Ohio

By Carl Bauer and Paul A. Uhlmann

Superintendent, Sewage Treatment Plant, Celina, Ohio, and Consulting Engineer, Columbus, Ohio, respectively

The Celina sewage treatment plant was built in 1939 and put in operation in February 1940. It consists of grit channels and wet well, a flash mixing tank, two flocculation tanks, two primary settling tanks, three aeration basins, two final settling tanks, a digester, and sludge-drying beds. The operating building basement contains three sewage pumps, a sludge pump, a gas-fired heater, and a circulating pump. On the first floor are the laboratory, the blower room with two electric-driven and one gas engine-driven blowers, and the chemical room housing the lime slaker and feeder, and the ferric sulfate feeder. Chemicals are stored on the second floor and fed into the hoppers extending through the ceiling of the first floor.

The plant was designed hydraulically for a dry-weather flow of 0.9 m.g.d., assuming 0.6 m.g.d. of domestic sewage and 0.3 m.g.d. of industrial wastes. As the strength of the combined wastes was unknown and had to be based on quite scanty information available, it was considered desirable to protect the biological process by a chemical pretreatment of the wastes in cases of shock loads, which had to be expected due to the fluctuations of the industrial wastes flows.

This special feature of the Celina plant proved to be very valuable and was responsible for the handling of unusual shock loads lasting from four to six weeks. Although the B.O.D. load from the city of 5,000 is about 835 lb. per day, the plant handled as much as 8,800 lb. per day, with a population equivalent of 52,800.

Sources of Wastes

The Celina treatment plant receives the following industrial wastes:

1. Canning wastes from the Stokely cannery, which used to pack throughout the year beans, hominy, asparagus, peas, beets, tomatoes, and pickles.
2. Wastes from milk powder production.
3. Wastes from stearic acid manufacture.

The wastes from these industries are discharged to the sewers in greatly fluctuating volumes and quite irregularly. There were times when milk wastes predominated, especially during spring. During the months of September and October the packing of tomatoes created peaks of B.O.D. loading.

Effects of Industrial Wastes

The effects of the industrial wastes on the treatment plant and its performance have been manifold and sometimes unusual, but trying.

Canning Wastes

The Celina plant was designed in 1938, when the cannery operated on a modest scale. A 25 per cent increase in production was considered as a possible maximum, but not likely for many years.

When the treatment plant was put in operation in February 1940, World War II influenced its operation considerably. War orders for canned products necessitated the doubling and trebling of various packs; the B.O.D. loadings on the treatment plant soared accordingly. As long as the rotary screen at the cannery was kept operating efficiently, no difficulties were experienced in handling these wastes. The rate of chemical feeding had to be adjusted according to the character of the wastes produced. Quite often a change was made in the packing to take care of rush orders.

Milk Wastes

Milk wastes normally did not cause any trouble. However, in spring, when improper cooling of the milk resulted in souring before or during processing, many times up to 25,000 lb. of skim milk per day were received at the plant, making the raw sewage flow look like a milk stream. The gas production increased immediately and was doubled within a short time.

These milk dumpings were as regular as spring, until 1948, when the city officials established a fine of $50 per day for the dumping of abnormal amounts of milk. Strangely enough, no more milk troubles were experienced. The manager reports that the fine was coincidental with better housekeeping methods adopted at the factory.

Stearic Acid Wastes

The wastes from the stearic acid plant could be treated for nine years without any particular troubles. They affected the pH of the combined wastes to the extent that, periodically the pH of the incoming raw sewage would fall below 2.

These wastes could be easily detected by their particular odor and by proper adjustment of the lime feed the pH was raised easily to above 7 in all tanks.

Unusual Experiences

A few unusual experiences with the industrial wastes are worth mentioning, as they illustrate the necessity of close cooperation by the industries with the plant operator.

Canning Wastes

Some years ago, during the peak of the tomato pack, the screen of the cannery broke down and was out of commission for about two weeks. Therefore, the treatment plant received unscreened tomato wastes in such enormous quantities the comminutor was unable to handle them and rotten tomatoes, pulp, etc., piled up against the bar screen. The screenings had to be removed manually and hauled to the dump. These heavy loads would temporarily upset the entire plant.

Milk Wastes

A few years ago the processing equipment at the creamery broke down one morning shortly after work started. The plant manager called for suggestions on how to handle the milk still loaded on the trucks. Permission was given to haul the 50,000 lb. out to the sewage plant, where it was pumped directly to the digester. In a few hours gas production increased to more than 1,000 cu. ft. per hour. This production continued for a period of two days. The milk in the holding tanks at the creamery, about 40,000 lb., had to be dumped to the sewers and treated with the rest of the flow. By using

this method and with the help of chemical pretreatment the plant was not upset.

Stearic Acid Wastes

As previously mentioned, no special troubles were experienced with the stearic acid wastes for nine years. However, about two years ago the plant efficiency began to drop from the usual 95 per cent reduction in B.O.D., until in March, 1951, it was down to 41 per cent.

Repeated negotiations with the factory owners did not result in any improvements until they were informed in April, 1951, that the State Department of Health had been asked to aid in solving this problem. Within a week the treatment plant was improving and during the first 28 days of May the average B.O.D. reduction was 97 per cent.

Summary

Summarizing experiences with industrial wastes at the Celina, Ohio, sewage treatment plant, the following conclusions can be drawn:

1. Each type of industrial waste discharged to the plant requires special attention and proper adjustment of chemical feeding.
2. Combined wastes with a population equivalent of more than 50,000 have been treated successfully for many weeks in succession without any reduction of plant efficiency, which exceeded 95 per cent. During such peaks of plant loadings, the ratio of industrial wastes to domestic sewage was 9 to 1.
3. Close cooperation of the industries with the plant operator is of utmost importance.
4. Without chemical pretreatment facilities and flexibility in the air input available at the plant, it would have been impossible to treat the combined wastes to the degree required by the small flow in Beaver Creek, the receiving stream.

TIPS AND QUIPS

"Spirited" Campaign

For some time the Illinois State Sanitary Water Board has been threatening penalties if the city of Mt. Vernon does not keep its sewage from Casey Fork Creek. However, the city's voters have turned down propositions to build modern sewage disposal works at two successive elections.

Recently the city administration came up with a new way of financing its defense against the abatement orders. The method involved hiring an attorney and resolving to pay him by appropriating 25 per cent of fees received from sale of liquor licenses during the fiscal year!

Pointers on Painting

Wire mesh fences and open objects of the same general type can be painted faster and better by using a regular push broom as a brush. As with other methods of applying the paint, proper preparation of the material to be painted is, of course, essential. Also, be sure to apply the coating from both sides to eliminate any lack of coverage.

If a fence or other open object is to be painted in the open, use "back-ups" made from canvas on a frame to prevent over-spray or brush splatter. The wind, if any, should be at the painter's back. Try using a low-pressure air gun to prevent excessive paint "carry-through," and catch the over-spray in pans beneath the back-ups for re-use. Ordinarily, a spray job does not deposit sufficient paint on a fence unless a two-coat application is made.

Extra time is consumed in setting up spray painting equipment and cleaning up after its use. Also, there

is a 10 to 20 per cent paint loss. Nevertheless, if the surface to be covered is rough, and particularly if much area is to be covered, spray painting is more economical than brush painting. Low-pressure air guns, by reducing overspray, make spray painting feasible in many areas where it was out of the question a few years ago.

Flat surfaces which can be hand brush painted usually can be painted with a roller coater with considerable time savings. Both brushes and roller coaters can be purchased with pressure paint feeds, taking one of the waste motions (consuming one-quarter to one-third of the painter's time) out of the painting operation. Roller painting can cover an area twice as fast as brush painting, with some brush work to finish up the job.

Snail Remedy

Hordes of prolific snails in the trickling filter and final tank at the Clinton, Ill., sewage treatment plant have long been a source of trouble. The problem suddenly cleared up, however, with the mysterious disappearance of the snails. Opening of a new metal industry plant in Clinton coincident with the departure of the snails leads Superintendent C. E. Corrington to suspect toxic metallic wastes in the sewage as the reason.

It's not all to the good, however, as there is some question as to whether or not the plant effluent is affected adversely by the same wastes!

Not At All Shy

The accompanying photo (Figure 1) was sent in by the consulting engineer on renovation and enlargement of an eastern sewage treatment plant. Note the healthy weed (yellow dock) which grew in only a few days' time from the scum accumulation in an Imhoff tank while the water level was lowered to facilitate piping changes.

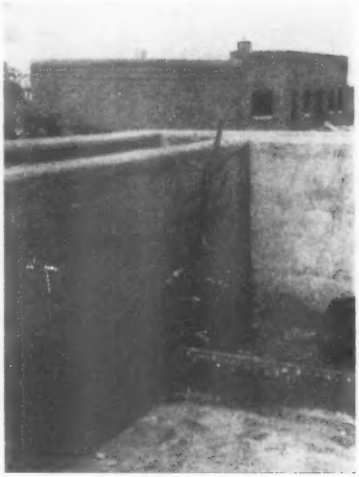


FIGURE 1.

Subtle Brush-Off

Use of color for specific purposes in industrial application has made tremendous strides in recent years. Perhaps the most practical use of color psychology we've run across, however, was offered during a discussion of plant painting and decorating at the Second Plant Maintenance Conference, held at Cleveland, Ohio, in January, 1951. Said a panel member in response to a question on color:

"We have used grey with a white ceiling in some applications, but it isn't too appealing a color. When you use it in a storeroom or warehouse, people get a feeling they want to get in, get what they want, and get out again."

That's one way of reducing the tendency to browse among the supplies and small tools!

Plant Safety Committee

How to get active operator participation in plant safety programs has always been a problem of some concern to superintendents. Despite the obvious benefits directly and indirectly accruing to the plant personnel by such

programs, lack of direct personal responsibility for the advancement of results leads to apathy on the part of many.

One means of circumventing such a condition is presented in the 1950–51 annual report of John R. Szymanski, superintendent of the New Britain, Conn., sewage treatment plant. Says the report:

Upon recommendation of the Sewage Disposal Commission, a Safety Committee was inaugurated at the sewage treatment plant and began functioning in January, 1950. The committee consists of the chief operator and a senior operator. The senior operator member of the committee changes each month, thus giving each senior operator an opportunity to work on the committee twice during a calendar year. This committee, although termed a Safety Committee, not only reports work hazards, but also recommends matters which indicate better working conditions. Each recommendation is carefully studied by the superintendent and then appropriate action is taken. Every two months a summary of the committee's report is presented to the Commission for approval.

During the fiscal year 1950–51 the following recommendations were made, and the following steps were taken to remedy any hazard present or difficulty encountered:

1. The elevated catwalk between the vacuum filters had a removable grating, which served as a walk. This grating had a tendency to slide somewhat; consequently, the grating walk was securely and permanently bolted.

2. The incinerator platform at the No. 4 hearth level had a partial guard rail, leaving 50 per cent of the incinerator circumference unprotected. Additional railing was installed.

3. Heavy and disagreeable odors accumulated in the basement area in the vicinity of the sump pit. This condition was remedied by the installation of a 24-in. heavy-duty exhaust fan.

4. The variable-speed air blower had an exposed section for brushes. To prevent any accidental contact, a heavy-duty safety screen was used to cover the exposed area.

5. Protruding objects at foot and head level were the cause of many complaints. Warning paint indicators and other warnings were posted to prevent sudden collisions.

6. In order to have available water for hosing of filters it was necessary to lay long lengths of hose to the existing water outlets, creating a hazard by having hose stretched across floors where a great deal of walking occurred. Water outlets were installed at all of the filters, the conditioning tank, and the sludge elevator.

7. A stationary chain hoist was used in the handling of ferric chloride barrels prior to solution making, thus forcing the worker to do a great deal of pushing and twisting before the container was secured in the correct position. To remedy this, a monorail was installed, and the same chain fall was hooked onto a swivel base.

8. The hand-controlled sludge wells on the final tanks were exposed and thus became a probable cause for accidents. Adequate hinged covers have been installed.

9. Although the outside tanks had guard rails at locations used most, it was decided to add further hand rails in order to have adequate protection at all points at all times.

Various miscellaneous repairs and alterations have resulted from this program for the benefit of the city and the employee. Furthermore, a program of this sort tends to uplift the morale of the employees, as it is a participation program with definite benefits derived.

More plants need similar Safety Committees at the operator level!

Book Reviews

Manometric Technique for Measurement of B.O.D. By Harvey F. Ludwig, William J. Oswald, and H. B. Gotaas. Series 44, Issue 2, Inst. of Eng. Research, Univ. of California (June 30, 1951).

This report is a manual of techniques on the use of the Warburg manometric method for measuring the B.O.D. of sewages and other wastes. The present work, as a continuation of continuing studies of the method, has been performed as part of an investigation on the subject of algae symbiosis in sewage oxidation ponds.

The manual emphasizes the careful techniques which must be employed if consistent reliable data are to be obtained. A simplified procedure is presented for use in making the necessary computations, and methods are suggested of seeding to give comparable results when making a series of tests extending over a long period of time.

The authors believe the method offers great advantages over the bottle test for most research or rigorous analytical studies, but that greatly simplified equipment, involving reduced investment and operating costs, must be developed before the method will be suitable for routine testing.

H. P. Orland

Manual for Water Works Operators. By L. C. Billings, editor-in-chief. Texas Water Works and Sewerage Short School. Third Edition, 1951. 573 pp. Price, $5.00. (Available through Texas State Dept. of Health, Austin, Tex.)

The third edition of this practical water works manual incorporates in its excellent treatment of basic considerations the many developments in this field since the 1943 (second) edition. Of interest to sewage works personnel are the chapters on sanitation of surface supplies, physical and chemical tests, financing, rate structures, and anti-stream pollution regulations.

H. P. Orland

The Municipal Year Book, 1951. By Clarence E. Ridley and Orin F. Nolting, editors. International City Managers' Association, Chicago 37, Ill. 1951. 588 pp. Price, $10.00.

The 18th volume of this highly informative compilation of data and analyses of trends in various phases of municipal activity brings up to date the regular features of the content and also covers many new cities and several new topics. As in past volumes, summary articles in each field review the significant events of the past year. Articles preceding each of 21 major tables analyze data reported by hundreds of cities. The tables themselves give greater coverage than heretofore, as the 1950 census gives 277 more cities with over 5,000 population.

A feature of the current volume is a listing, for each city over 5,000, of the 1950 census population figure, the 1940 population, the per cent increase or decrease, and an analysis of urban and metropolitan area population changes. Planners and population forecasters should find this feature alone of great value.

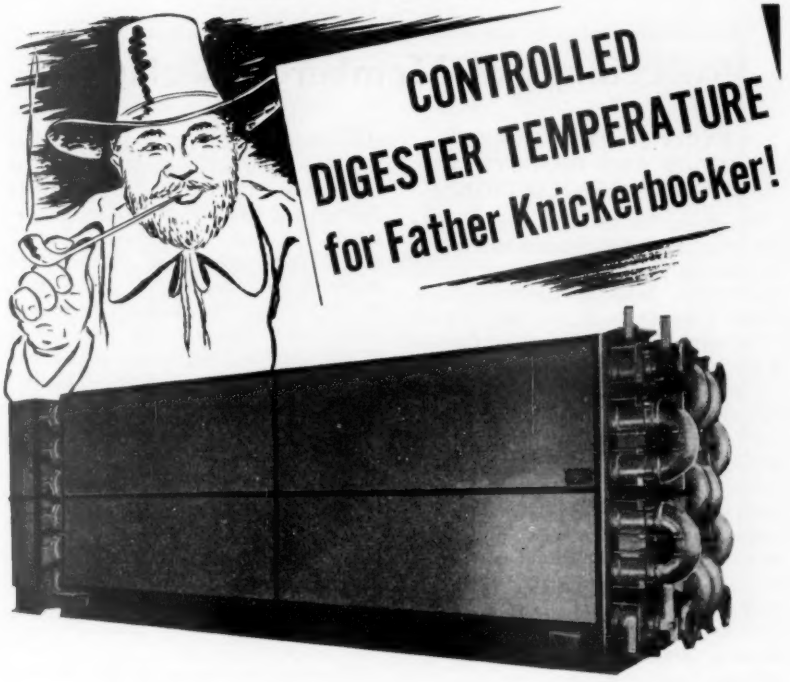
H. P. Orland

Water Supply and Treatment. 7th Edition. By Charles P. Hoover. Nat. Lime Assn., Washington, D. C. (1951). 211 pp. Price, $1.25.

This latest edition is published in cloth binding, instead of the paper binding form of previous editions. It also contains a number of important revisions covering disposal and reclamation of lime sludge, the versenate method of determining water hardness, methods of recarbonating softened water, and polystyrene base exchange.

A widely used book on water treatment, the book in its previous editions has been translated into several different languages by foreign organizations for their own use.

H. P. Orland



Latest addition to the P. F. T. sewage treatment equipment serving New York and environs are four P. F. T. No. 634 Heat Exchanger units, one of which is shown above, installed at the Hunt's Point Sewage Treatment Plant.

Each unit has an output of 3,625,000 B.t.u. per hour and a combined output of 14,500,000 B.t.u. per hour.

Waste heat from sewage sludge gas engines is utilized. Sludge from the digesters is circulated through 6-inch tubes in the P. F. T. Heat Exchanger which are within 8-inch tubes, forming an annular space through which engine jacket cooling water is circulated to provide efficient heating of the sludge. Raw sludge is preheated in the same unit. .

This highly efficient method of preheating raw sludge and maintaining sludge in the digester at optimum temperature is proving a boon to many cities. Similarly, P. F. T. Digester Heaters utilize sludge gas as fuel to heat the water bath enveloping the sludge tubes. Complete data on this equipment is contained in Bulletin 235—which will be sent on request.

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Proceedings of Member Associations

PACIFIC NORTHWEST SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

Scheduled for two full days for the first time, the 1951 Annual Meeting of the Pacific Northwest Sewage Works Association, held at the Vancouver Hotel, Vancouver, B. C., May 15–16, 1951, attracted the largest attendance in the history of the organization.

A paper on "Important Activities in Pollution Control," by R. L. McGrath, U.S.P.H.S., Portland, Ore., was followed by "Sewage Pumping Plant Problems," in which design, variable speed pumping units, selection of pumps, and maintenance of pumps were discussed by a panel consisting of Ray E. Koon, Portland, Ore.; H. Loren Thompson, Portland, Ore.; Fred Merryfield, Corvallis, Ore.; W. P. McNamara, Seattle, Wash.; and H. K. Johnson, Seattle, Wash.

At the luncheon on May 15, R. W. Beach spoke on "Administration of Municipal Sewer Projects." This was followed by an afternoon session devoted primarily to papers reporting developments in sewage treatment activities of several of the larger cities in the Pacific Northwest, as follows:

"The Tacoma Sewage Treatment Plant," by C. S. Seabrook and R. R. Kennedy, San Francisco, California.

"The Portland Sewage Treatment Plant," by J. W. Cunningham, Portland, Ore.

"Operating the Boise Sewage Treatment Plant," by Andrew Wahl, Boise.

"The Seattle Sewage Works Program," by R. W. Finke.

A paper on "The Use of Ozone in Waste Treatment," by Prof. R. G. Tyler, University of Washington, concluded the session.

At the Annual Dinner Meeting on the evening of May 15, a new constitution was adopted changing the name of the Association to Pacific Northwest Sewage and Industrial Wastes Association. The first "Operations Award" of the Association was presented to Earl Snodie, operator of the Seattle-Tacoma Airport sewage treatment plant, with honorable mention going to Andrew Wahl, superintendent of the Boise, Idaho, sewage treatment plant.

Officers elected to serve during 1951–52 were:

President: W. W. Tinniswood, Moscow, Idaho.
Vice-President: C. M. Everts, Jr., Portland, Ore.
FSIWA Director: W. P. Hughes, Lewiston, Idaho.
Secretary-Treasurer: R. O. Sylvester, Seattle, Wash.

The morning session on May 16 was devoted to an Operator's Forum. Topics discussed included odor control, digester heating problems, treatment plant faults, grit chamber problems, and laboratory control of operation. The discussions were led by R. O. Sylvester, N. E. Waggoner, and R. E. Leaver.

A panel discussion by C. M. Howard, G. G. Ingman, and J. W. Cunningham on "Problems of Sewer Line Construction" opened the May 16 afternoon session. This was followed by papers as follows:

"Land Disposal of Sewage and Industrial Wastes," by A. H. Rice.

"Critical Materials in Sewage Works Construction," by P. M. Crawford, regional director, U. S. Dept. of Commerce.

ROBERT E. LEAVER,
Secretary-Treasurer

(*Continued on page 402a*)

New York's City Hall, completed in 1811, as it looked 100 years ago

The City of New York has several cast iron water mains in service that were laid more than a century ago. They are part of approximately 5,000 miles of cast iron mains representing about 98% of all the pipe in New York's distribution system. The contrast in traffic and construction, above and underground, today and 100 years ago, is fantastic. Yet the shock-strength, crushing-strength and and beam-strength of cast iron mains have enabled them to withstand the unforeseen stresses imposed by vast changes. Because of these strength factors and effective resistance to corrosion, cast iron water and gas mains laid over 100 years ago, are still serving in the streets of 38 cities in the United States and Canada.

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The Fourth Joint Meeting of the New York Sewage and Industrial Wastes Association and the New England Sewage Works Association was held at the Hotel Kimball, Springfield, Mass., June 7–8, 1951. Registration totaled 267 members and guests.

The technical program included the following papers:

"Sewage Works Aspects of Radiological Problems," by LeRoy W. VanKleeck, Principal Sanitary Engineer, Connecticut State Department of Health.

"The Relation of B.O.D. to Stream Deoxygenation," by Walter E. Williams, Lederle Laboratories Division, American Cyanamid Co., Pearl River, N. Y.

"Review of Some Industrial Waste Treatment Plants in Connecticut," by Willis J. Snow, Senior Sanitary Engineer, Connecticut State Water Commission.

"Industrial Waste Treatment Developments in the General Electric Company," by K. S. Watson, Manufacturing Policy Division, General Electric Co., Schenectady, N. Y.

The first day's technical program closed with a symposium on "Problems Caused by Industrial Wastes at Sewage Treatment Plants," under the leadership of George E. Symons, Managing Editor, *Water & Sewage Works*, New York, N. Y. The symposium featured six prepared discussions.

The second morning was devoted to an Operators' Round Table on the subject "Three R's of Sewage Treatment (Recording, Reporting, Repairing)," under the leadership of Frank L. Flood, Partner, Metcalf & Eddy, Boston.

(*Continued on page 404a*)

The original primary Spiraflo Clarifier, installed at Flora, Ill. in 1937, now averages better than 50% B.O.D. removal when operating in excess of 1000 gallons of surface rate and 1½ hours of detention. The final tank is also a Spiraflo.

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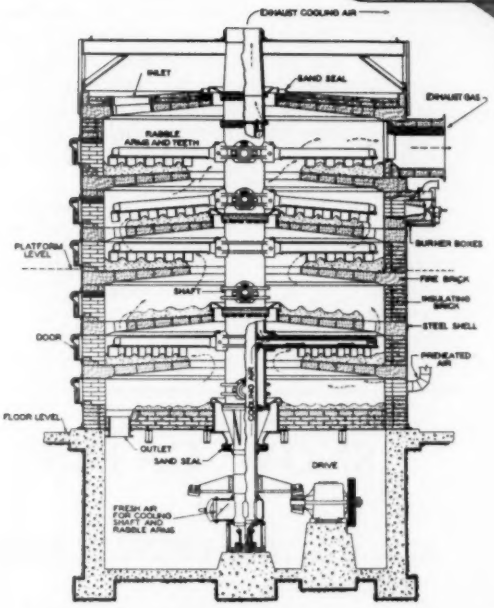

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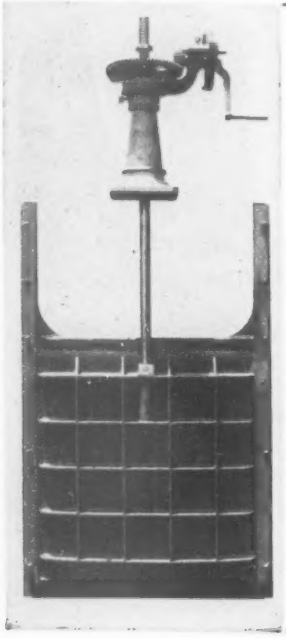
Following the luncheon on June 7th Mayor Daniel B. Brunton of Springfield extended the greetings of the city of Springfield and Federation Secretary Wisely brought the members up to date as to the present status of critical materials and the most recent activities of federal agencies in their control. At the conclusion of his talk Mr. Wisely presented the 1951 Bedell Award for the NESWA to LeRoy W. VanKleeck in recognition of his outstanding service to that Association. President John M. MacCrea of the New York Association then called upon C. E. Irving, Chairman of the Rating Committee, who presented the following awards on behalf of that Association: Engraved certificate to Edward Smith, Superintendent of the Niagara Falls, New York Sewage Treatment Works, for the best report in the 10,000 to 100,000 population group and a similar certificate to Mr. William Edwards, operator of sewage treatment works of the Gowanda State Hospital, for the best report in the under 10,000 population group.

Entertainment features included a ladies' luncheon at Wiggins Tavern, Northampton, Mass., a social hour sponsored by the Water and Sewage Works Manufacturers' Association, a special showing at the Springfield Planetarium, and luncheon at Storrowton Village on the Eastern States Exposition Grounds. The Joint Meeting closed with a tour of the Colonial Village at Storrowton and an inspection of the Springfield main sewage treatment plant.

R. C. SWEENEY,
Secretary, NYSIWA

WALTER E. MERRILL,
Secretary, NESWA



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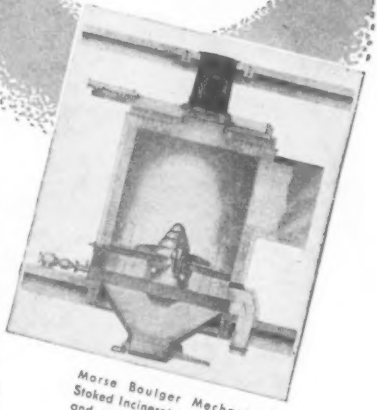

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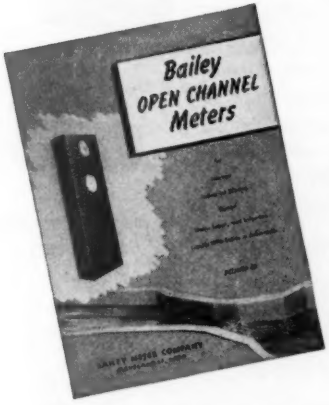

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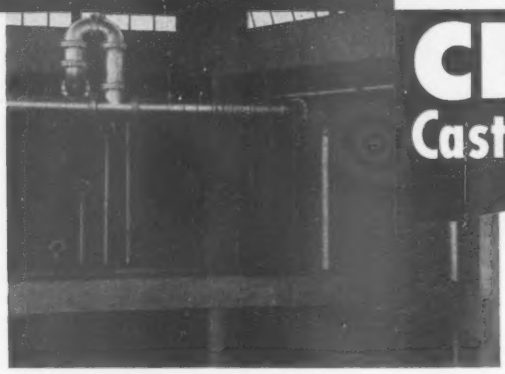

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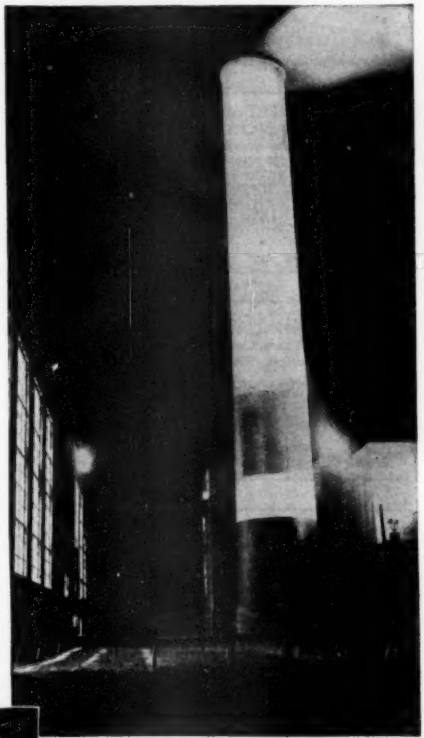

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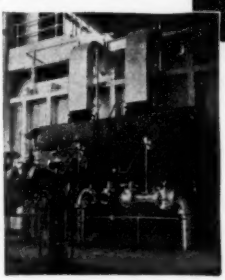

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